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PILOT STUDY OF GAS PRODUCTION  
ANALYSIS METHODS APPLIED TO  
COTTAGEVILLE FIELD

July, 1978

J. Negus de Wys and R. C. Shumaker

Prepared for  
UNITED STATES DEPARTMENT OF ENERGY  
Morgantown Energy Research Center  
Morgantown, WV

Submitted by  
West Virginia University  
Department of Geology and Geography  
Morgantown, WV 26506

Under  
Contract EY-76-C-05-5194

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PILOT STUDY OF GAS PRODUCTION ANALYSIS METHODS  
APPLIED TO COTTAGEVILLE FIELD

J. Negus de Wys  
R. C. Shumaker

ABSTRACT

Gas production data from 63 wells in the Cottageville Gas Field, producing from Devonian shales, are studied in relationship to structure above and below the producing horizons, isopach data and dip of producing shales, and basement structure trends. Gas production data are studied from several aspects including highest accumulated production, mean annual production, initial well pressure, and calculated loss ratio values for four (4) different time periods.

A trend correlation of these parameters is presented. The initial pressure trends correlate with all geological parameters, i.e., Devonian shale dip and strike, 40-50° NE fracture facies trend, structure on the base of the Huron, structure on the top of the Onondaga, and the basement magnetic density data. Production data trends show greatest correlation with structure on the top of the Onondaga and with fracture facies trends from the Baler well. Production decline data in terms of loss ratio values show trends correlating with all geologic parameters except the Onondaga. Two loss ratio maps correlate with the structure on the bottom of the Huron. The strike of Onondaga structure correlates with the 40-50° NE fracture facies trend.

These parameters may be generally viewed as the production maps representing free gas pockets and migration-accumulation trends; the loss ratios as possible permeability and migration trend indicators; and the geologic parameters as possible constraints or causative agents.

The lack of correlation of geologic parameters with production data trends a few degrees west of north may be suggestive of a fault or faults in that direction, providing the correlative causative agent. This is not an unreasonable possibility from the production data maps.

It is concluded that this approach could be useful in gas exploration and development evaluation of Appalachian Devonian shale gas fields. Similar relationships will be examined in the Eastern Kentucky Gas Field (s) Study presently in progress.

## INTRODUCTION

The purpose of this study is to apply various methods of gas production data analysis to gas field data in order to objectively evaluate and explore relationships in the production history of the Cottageville gas field in the Devonian shale. An understanding of such relationships may contribute to estimation of recoverable reserves and to conclusions of hypotheses in the study area which may be applied to other potential gas producing shale areas. A method of approach to gas field study and possible implications have thus evolved from this study.

The scope of the study is the gas production from 63 wells from Devonian shales in the southwestern portion of the Cottageville Gas Field in southwestern Jackson County and eastern Mason County. The earliest well considered in this study was drilled in 1920; the most recent included in the study was drilled in 1976.

Production data has been used as given. No standardization or altering of the data has been attempted. Second year production figures have been substituted for first year in wells where completion was late in the year and thus resulted in a low per annum production report.

The data analysis includes mapping of production data in various relationships and decline curve analysis by computer programs and historical relationships. Tentative conclusions are drawn from a comparison of these data depictions.

## DATA

One well in the westernmost part of the study area was drilled in 1930 and one in the northwestern part in 1931 (see Figure 1). These were followed after eleven years by one well drilled in 1942 and one in 1947. Nine more wells of the group studied were drilled in the period 1948-49 and five in 1951. In 1950 the major portion of the northeast-southwest trend of the field was drilled with 37 wells, followed in the period of 1974-76 with five more. The earlier well production may have had some effect on gas pressures and production peaks in later wells. This is observed by comparison of the Initial Gas Pressure Map (Figure 2) with the Historical Sequence Map. To be more clearly understood the initial gas pressures could be considered by chronological groupings. The lower pressures encountered close to earlier high pressure areas may then be interpreted in several instances as the results of the earlier gas production lowering pressures in what may be fracture connected areas.

Gas production data was tabulated by year. From this tabulation the highest annual production, accumulated total production, first five years accumulated production, and mean production are computed. Most of these computations are fairly standard procedure, however, loss ratios may be unfamiliar. Loss ratios (Arps, 1944; Campbell, 1973) are computed in this study

as follows:

$$d = \frac{q_1 - q}{q_1}$$

where: d = fraction or percent production lost

$q_1 - q$  = The gas production for the first year considered  
less the gas production for the second year considered.

$q_1$  = The gas production for the first year considered.

The resultant value represents the slant of the gas production decline curve for the period under consideration. Loss ratio values are computed for 1-2 years, 2-3 years, 3-4 years, and 1-5 years.

Structure contour maps are shown for the top of the Onondaga below the Devonian shales and for the structure at the bottom of the Huron shales which overlie the producing Devonian shales. The trend strike of the Devonian shale isopachs (N 60° E) is also used in the map comparison.

Isopressure contours are drawn on the initial pressure data obtained following well completion. No adjustment of pressure data to standardize these data has been attempted.

#### DATA ANALYSIS

The data computed for each well is contoured on the following series of maps: (Figures 1-14). These are included as both black line figures with shading of high value areas and as transparencies in the pocket in the back of this report for map-to-map comparison.

The trends of the contour axes on each map are traced onto a common overlay (Figure 13). These trends are tabled according to correlation of trend angle with other sections of the study area (Table 1) and by correlation of angle within the same segment of the study area (Table 2).

From the trend groupings a comparison chart (Figure 14) and trend correlation (Table 3) are compiled. The comparison chart shows with which maps a given map shows trend correlation within the study area (outlined intersection) and within specific area segments (hatched intersection). A higher degree of correlation, where more than one trend angle is correlated with a given map, is shown by crosshatched intersections. Table 4 compares the map trends with core fracture orientations from the Baler well.

From the point of view of geology the Top of Onondaga Structure (Figure 10), Bottom of Huron Shales Structure (Figure 11), and the Devonian Shale Isopach trend (N 60° E) show interesting relationships with the other maps. The structure on the Top of the Onondaga (Figure 10) shows trend correlation

with Total Accumulated Production (Figure 4) within the same area segment, with Highest Annual Production (Figure 2) and with First Five Years Accumulated Production (Figure 3) within the study area.

Structure at the Bottom of the Huron Shales (Figure 11) shows correlation with Gas Production Decline Loss Ratio 2-3 years (Figure 7), Gas Production Decline Loss Ratio 3-4 years (Figure 8), and Gas Production Decline Loss Ratio 1-5 years (Figure 9). All but one (the first year) decline curves are thus correlated in trend axes to the Bottom of the Huron shales. Yet the Total Production, Highest Annual Production and Five Years Accumulated Production show correlation with the Onondaga below. This latter group would appear to represent available gas accumulation. The relationship to the Huron is more in terms of how the production declines which may be thought of in terms of free gas, adsorbed gas and absorbed gas (Figure 18). Also of interest is the fact that none of the maps related in these two groups are cross related to both structure maps.

The Devonian Shale isopach contours show correlation with the isopressure: Initial Pressure map (Figure 12). The total Accumulated Production Map shows trend correlation with the inferred depositional dip of the Devonian shales.

The Isopressure map also correlated with Highest Annual Production (Figure 2), First Five Years Accumulated Production (Figure 3), and Total Accumulated Production (Figure 4) within the same area segments. In addition, trend correlation in other parts of the field is observed with Mean Annual Production (Figure 5), Gas Production Decline 1-2 years (Figure 6), and Gas Production Decline 3-4 years (Figure 8).

The chronological plot of field production data is shown in Figure 15. Three families of curves are observed to separate in the 1948-1976 period of production. Thirty-three wells were plotted for this period and it appears the remaining would fall generally in the three families observed. The three wells represented in Family 1 and three wells in Family 2 are shown on the Trend Map (Figure 13). A northwest trend (N 88° E) is observed to fit five of these wells, with no correlation to any of the other trends in that segment, but only 8° off the depositional dip of the Devonian shales as inferred from the isopach strike of N 6° E.

An average production decline curve was computed from 30 Cottageville wells which had produced at least 12-13 years. Figure 16 shows a comparison of this average with an average curve for the Clinton sandstone production (236 wells) and an average for Devonian shale wells (282 wells) from various basin areas. The data for the latter two curves are from Foster, 1977. The initial decline slope of the Cottageville average curve is more similar to the more porous sandstone production decline curve. This may be due to more free gas in Devonian fractures in a "fracture facies" than is found in some of the other Devonian wells. The lower portion of the Cottageville curve more closely resembles the average Devonian curve. This lower portion could be interpreted to be the result more adsorbed and absorbed gas and would thus be expected to show such a similarity. Such a comparison might suggest more of a fracture facies in Cottageville wells than in wells composing the compared



Devonian shales well curve of Foster.

The term fracture facies is proposed for use in certain Devonian shales with the following definition of the term: rock facies containing fractures that occur over a wide area within a distinct stratigraphic interval. As applied to Cottageville field, the image conveyed is similar to a stratigraphic trap - but one where the porosity is caused by laterally limited fracture porosity with a distinct stratigraphic interval.

A further comparison is shown in Figure 17 of the Average Cottageville Production Decline curve with averaged production decline curves for Devonian shale wells in Lincoln, Mingo, and Wayne Counties, West Virginia. The Cottageville average is most similar to the 100-200 Mcf/Day curve for production from the other counties, with the exception of the higher peak production seen in Cottageville. This may indicate more of a "fracture facies" in the Cottageville Field.

The average curve for each of the three families of production curves observed in Cottageville are also shown for comparison with the averaged curves for the other West Virginia counties. The upper two curves from Bagnall appear to be similar to Family #1 in Cottageville, and Family #2 and #3 curves are similar to the lower two curves respectively.

In Figure 18 a schematic sketch of fractures in Devonian shale shows free gas molecules, in open spaces related to peak production, adsorbed gas molecules on fracture facies related to intermediate section of production decline curve, and absorbed gas molecules related to long term slower decline and lower production end of the curve. Over 20-25 year production life, the lower end of the curve comprises up to 90% of the production curve in terms of time. In Family #3 peak production may account for up to about 22% of total gas production; intermediate rate of production may account for up to 30% of total gas production, and the slower rate may account for up to 48% of total gas production over a 25 year well life. Percentages in the higher two curves families, #1 and #2 may be shifted considerably toward the lower end, with as much as 61% of total gas production in a single well represented by the lower portion of the production decline curve.

#### COMPUTER PROGRAM APPLIED TO PRODUCTION DECLINE CURVES

It was attempted by computer to find the "best" fitting curve equation to approximate gas production from selected wells from the Cottageville area figures 21-23. Starting with an existing computer program, the object of the program was to find by a least-squares procedure, the best-fitting curve of two equations: A. The exponential equation of  $Y(\text{Prod}) = B_0$  (an estimated constant found by the program) times 'e' (2.71828) which is raised to the power  $B_1$  (another estimated constant) times  $X$  (Time).. $[\text{Prod} = B_0 \times E^{(B_1 \times \text{Time})}]$ . B. The second equation (a hyperbolic function) was of the form  $Y = B_0 \times (B_1 + X)^{B_2}$ ; where  $B_0$ ,  $B_1$ , and  $B_2$  are again constant found by the program and  $Y$  = Production and  $X$  = Time, measured in years.

The exponential curve, using the formula previously referred to, is found

to reasonably fit the actual measured output. By using the coefficient of determinant ( $R^2$ ) an estimate is obtained of goodness of fit to the data.  $R^2$  is the total amount of variance of the data from the mean or average, that is explained by the curve in question. With only one independent variable, time, the most important results are the  $R^2$  value and the standard deviations on the B values being estimated. Accuracy in making future predictions on the production of the well is related to these two values. Based on observations of the exponential equation (curve), its graph, and knowledge of its properties, it appears to have properties which permit a good estimate of future production and give at least a reasonable estimate of a well life. (This is opposed to a hyperbolic type equation which can give good estimates of the immediate future but tends to over estimate the productive life of a well.)

The higher ordered polynomial models are a linear transformation regression model of the form  $Y = B_0 + B_1X + B_2 X^2 + B_3 X^3$  --- ( $Y = \text{Prod.}$ ,  $X = \text{Time}$ ). These show the non-linearity of the model. A combination of these quadratic, cubic, and high ordered transform shows a very good fit to the data, which is expected. While these curves do not present a theoretical explanation of the data and its characteristics, they do approximate the data very well over the range of time being observed and could be used for short-term projection. Reciprocal and combination with the polynomial equations again are not along a theoretical decline curve, but are considered in order to best approximate the curves as they stand. They also can be used for short-term predictions and show the dependency of production upon time. Analysis appeared to substantiate that all of the wells compared with the computer curves could be represented to a fairly high degree of accuracy ( $R^2 .95$ ) by  $\text{Prod} \approx B_0 + B_1 (\text{Time}^0) + B_2 (\text{Time}^{1/2}) + B_3 (\text{Time}^2)$ , shown in the figures as Polynomial Reciprocal.

A power curve of the type  $\text{Prod} = B_0 \times \text{Time}^{B_1}$  approximated the actual curve almost as well as the exponential curve. Not all of the wells have been tested against this equation and possible manipulation of it might prove effective.

## DISCUSSION

Devonian shales underlie approximately 100,000 square miles in Kentucky, Ohio, West Virginia, Pennsylvania and New York. It has been estimated that this area contains about 460 trillion tons of shale readily accessible to drilling, and most of this at about 10,000 feet in depth (Columbia Gas System).

The horizon of "brown shales" from which most gas has been produced is a 400' section with finer grain size, darker colors with spores (i.e. Foerstia) reported. Above this zone is 1,200 feet of gray to greenish-gray shales with sandy and silty zones and a dark gray to black interval. Grain size coarsens upward from the producing horizon. Below the producing horizon is 300-400 feet of greenish-gray shale with no silt and below that 200-400 feet of lower black shale, calcareous in the bottom portion (Tully ls.). Gas has been produced from the Brown Shale horizon for nearly 50 years from low-volume shallow wells in the western one-third of West Virginia.

Up to 4.4% by weight organic content is found in the brown shales.

Porosity in Devonian shales is very low. In two Jackson County wells in West Virginia, porosity ranged from .1 - 4.6% with overburden of 1650 PSI and 3700 PSI (obtained by oil method). By comparison, highly productive sandstone reservoirs show 10-20% of total rock volume. Most pore space found in shales is between the mineral crystals or grains and in micro and macro-fractures (Science Applications, Inc., 1977).

Permeability values for the same two Jackson County wells ranges from .0001 - .001 Md with overburden pressures of 1650 and 3700 PSI. This is very low permeability which limits the rate of gas production by the rate at which gas can diffuse through the matrix and reach a free surface such as a bore hole or a fracture. Compared with sandstones this results in low production rates, but extended production life. Clastic silt-size quartz and feldspar are commonly segregated into lenses parallel to bedding in the very dark, organic-rich shale specimens. Higher permeability in such lenses may permit migration through such silt zones to accumulation fracture facies areas.

Mineral lined vertical fractures were commonly noted in the pay zones of two wells in western and southwestern West Virginia. In one core from western West Virginia (Wheeler et al.), filled and unfilled natural fractures resemble parts of nearly vertical systematic joints. The fractures strike N 40° - 50° E above the pay zone (Table 4), and show four dominant orientations within the pay zone. As noted earlier a higher percentage of total production appears to be the result of absorbed (matrix) and adsorbed (on fracture surfaces) than from free gas. Wheeler et al suggest that fracture density on a larger scale may be influenced by old or reactivated suballochthon faults, by allochthony itself, by erosional release, or by two or more of these interacting. They further suggest slickensides can seal fractures and thus decrease permeability.

Rogers (1971) concludes from stratigraphic evidence that after a period

of extensional tectonics accompanying the main subsidence, a period of true compression ensued in late Mississippian to early Permian time during which the final group of clastic sediments were deposited and the whole section deformed.

The outline of Brown shale production in West Virginia coincides strikingly with the trend of the Rome Trough. Martin and Nuckols (1976) postulated that fractures in the Devonian shales in the gas-producing areas result from reactivated movement of the basement fault blocks comprising the Rome Trough. Weaver, (1972,) noted the relationship of the structure to Devonian gas production. Figure 24 shows the basement structure and magnetic intensity values in the Cottageville area (Shumaker, 1978). The magnetic intensity contours are closely correlated with the edge of the Rome Trough which comprises a valley rift system on the Precambrian basement level. It is reasonable to assume that fracture facies developed over fault movements associated with the Rome Trough structure.

Selin (1976) suggested a fracture factor similar to the Kazimi 1962 model for fractured rock gas reservoir computations. Such a factor may well improve the reservoir calculation for the fractured Devonian shale wells and fields. It is beyond the scope of this study to explore this possibility but the potential of such a fracture factor applied to production from a fracture facies is recognized.

Erwin et al (1976) described the problem of the Devonian shales as the nature, cause, timing of fractures, relation to regional stress and structural patterns below, within, and above the Devonian shales. This pilot study of gas production analysis methods applied to a portion of the Cottageville Field is an attempt to look at these relationships in terms of axial trends to examine what correlations may exist. Highest annual production could be indicative of porosity, fractures (permeability), gas entrapment, migration, and possibly connection with other wells (when compared with chronology of drilling). First five years total accumulation may represent aspects of permeability, total gas reserves, gas pressures. Total accumulation should reflect all the factors related to five year production plus a stronger indication of permeability, and reserves. Mean of Total Accumulation may show a field porosity trend and permeability interrelationship of wells. This may be one of the better indicators of reserves. Loss Ratio maps are related to Permeability, Pressure and Supply.

A comparison of data along a cross-section A - A' (on Drilling Date Map Figure 1) is made for Drilling Dates, Structure on the Bottom of the Huron Shale, Structure on the Top of the Onondaga, Initial Pressure, Accumulated Total Production, Mean Production, and Loss Ratios for 1st, 2nd, and 3rd years of Production, shown in Figure 25. This method also shows interesting relationships which may be worthwhile studying. The peak production trend of the 1950 wells appears to roughly parallel the strike on the gently dipping Onondaga below the Devonian shales.

Further analysis and application of these methods to a study in eastern

Kentucky is presently being undertaken. The degree of correlation of trends and separation of correlations with geologic data appears encouraging.

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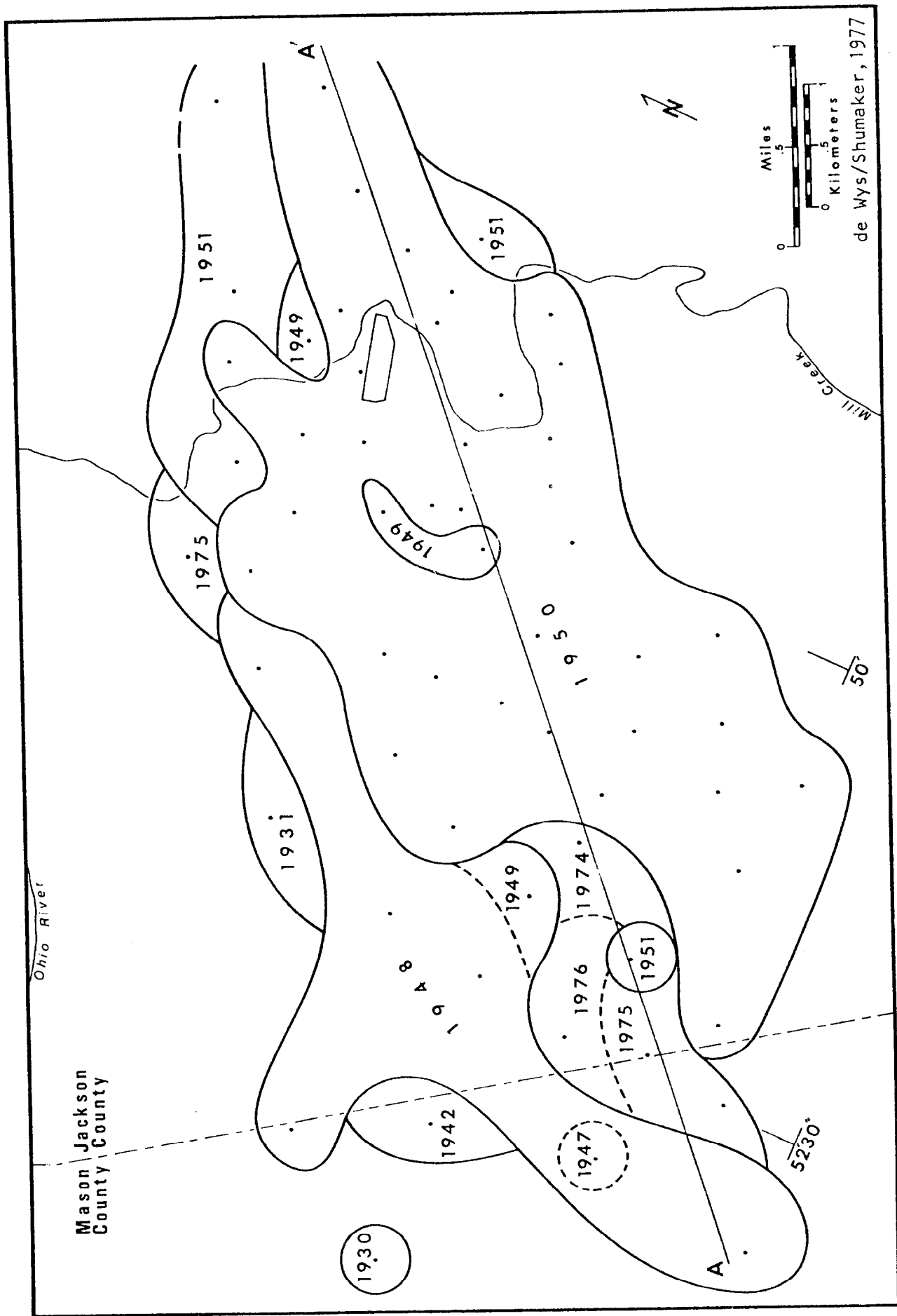


FIGURE 1- Drilling Completion Dates. Area= Drilling date of completion.



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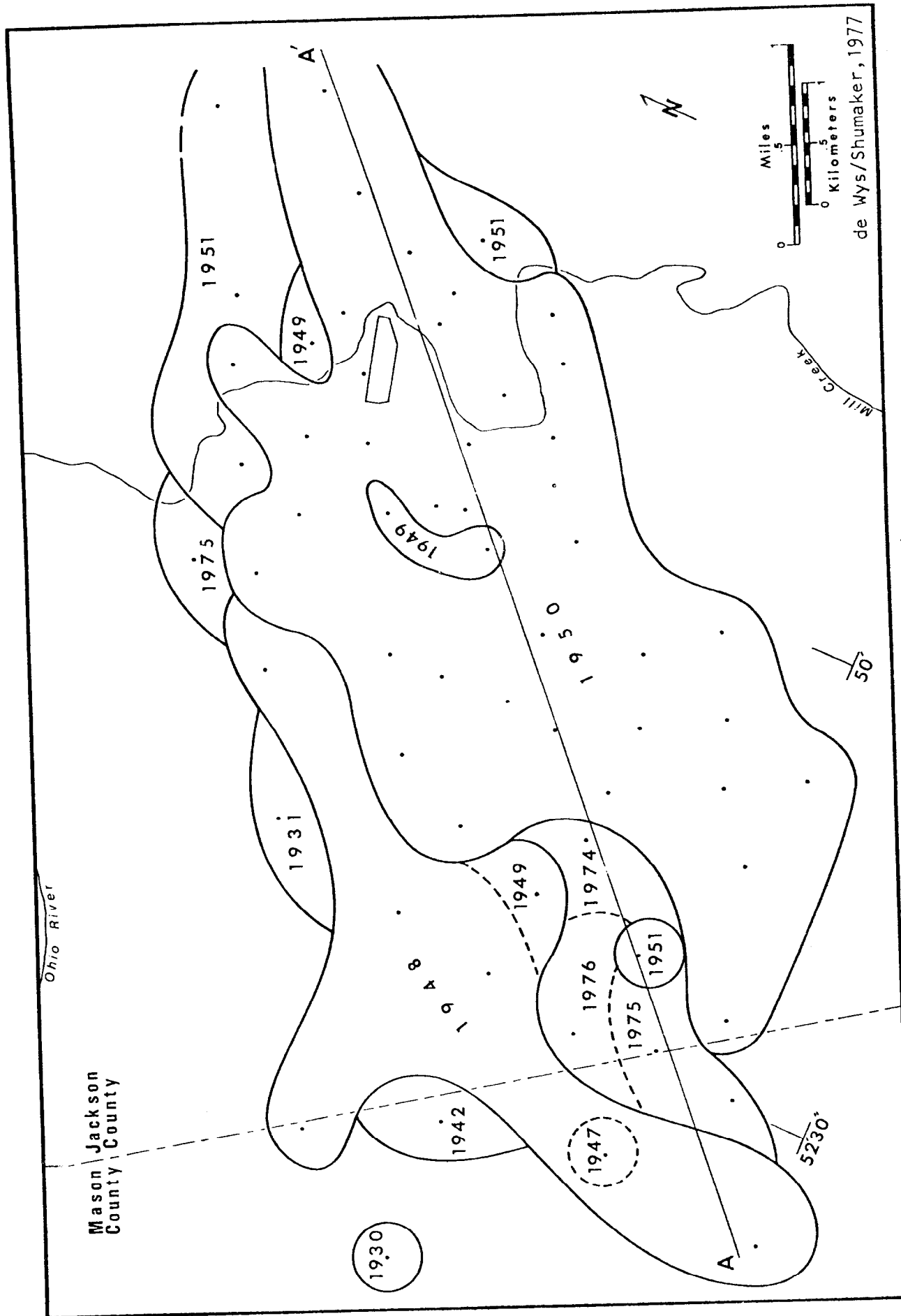


FIGURE 1- Drilling Completion Dates. Area= Drilling date of completion.

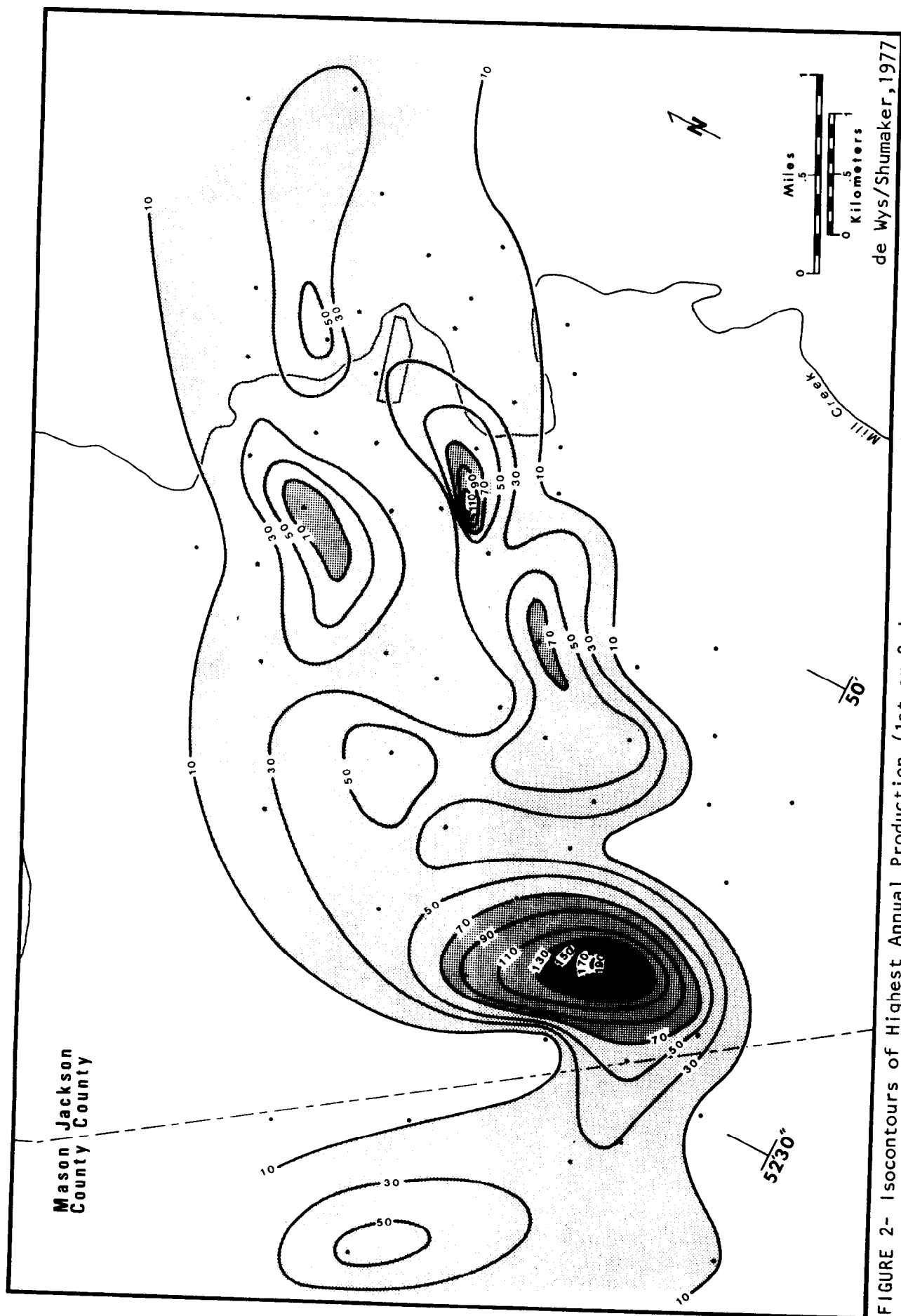


FIGURE 2- Isocontours of Highest Annual Production (1st or 2nd year production). Contour Interval= 20MMcf/yr.  
 de Wysz/Shumaker, 1977

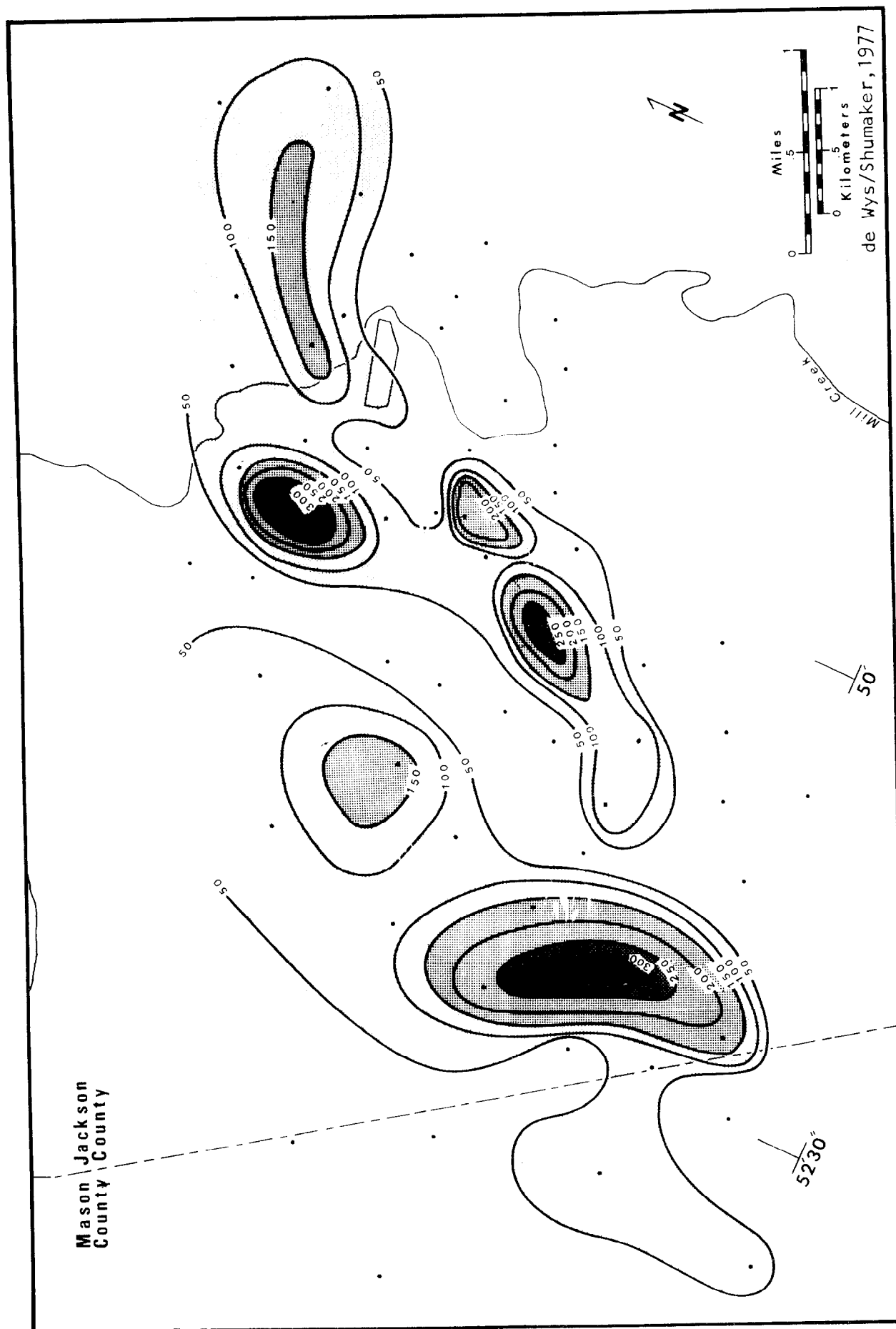
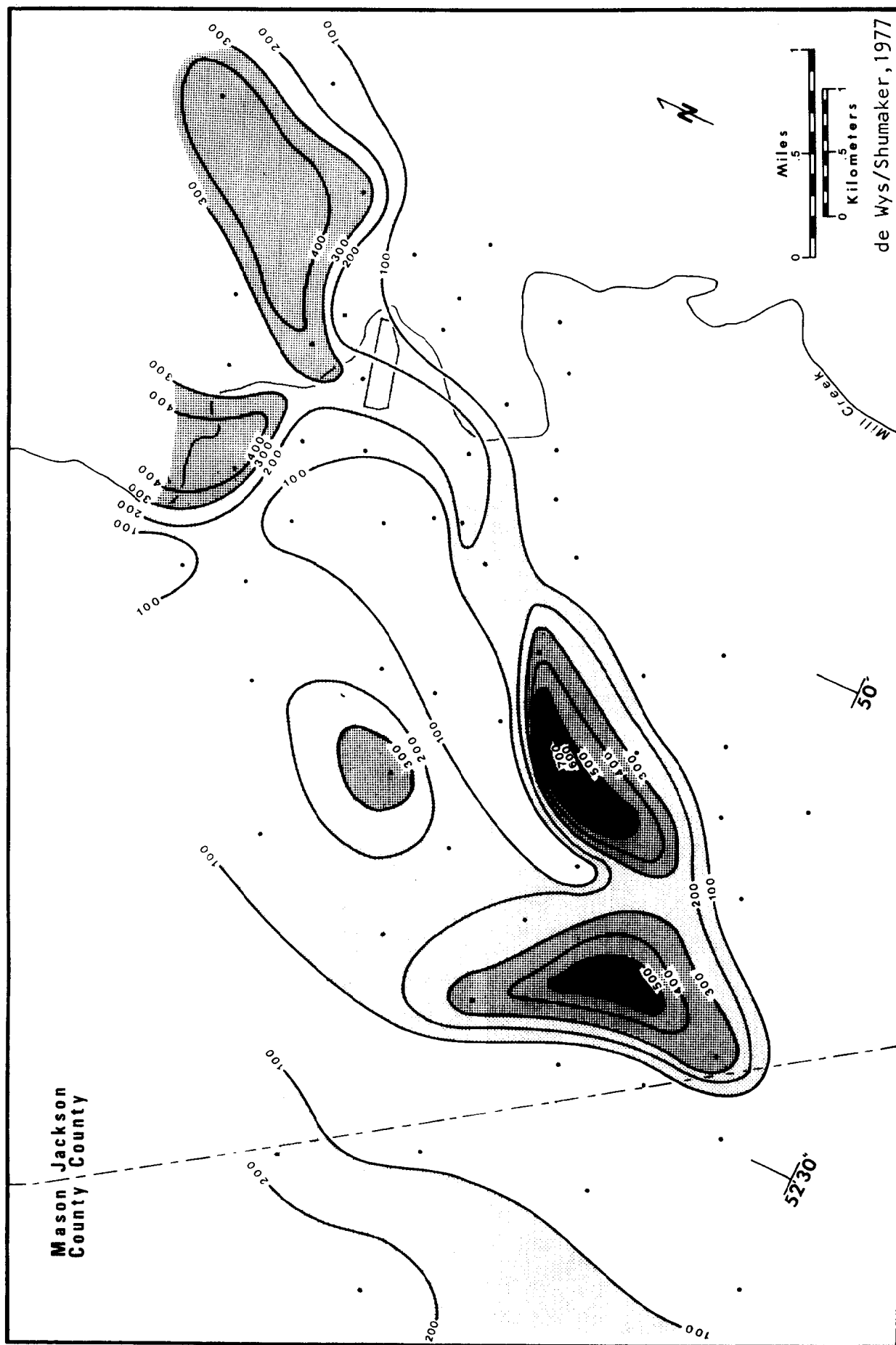


FIGURE 3- Isocontours of First Five Years Accumulated Gas Production. Contour Interval= 50MMcf/yr.



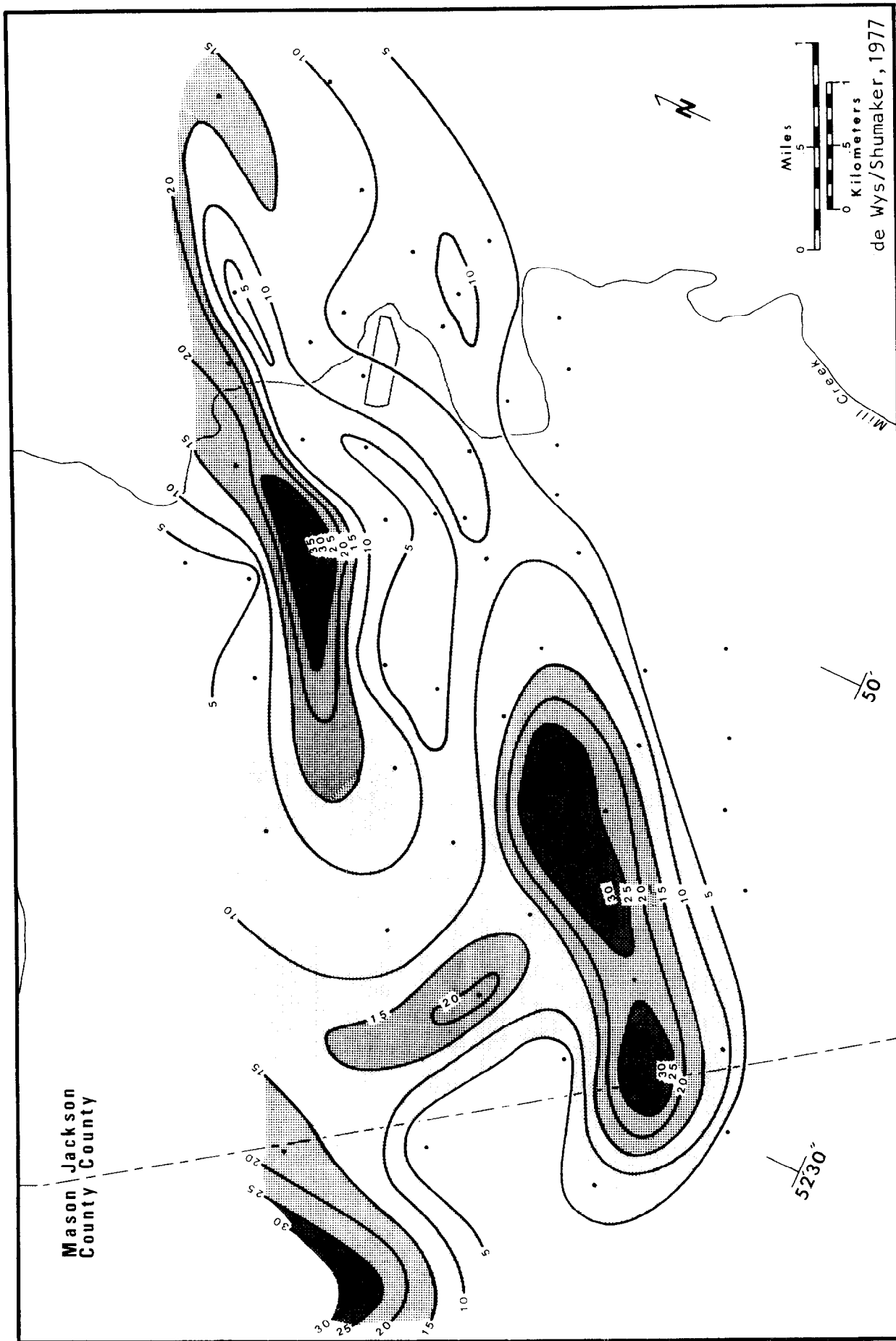


FIGURE 5- Isocontours of Mean Annual Gas Production. Contour Interval= 5MMcf

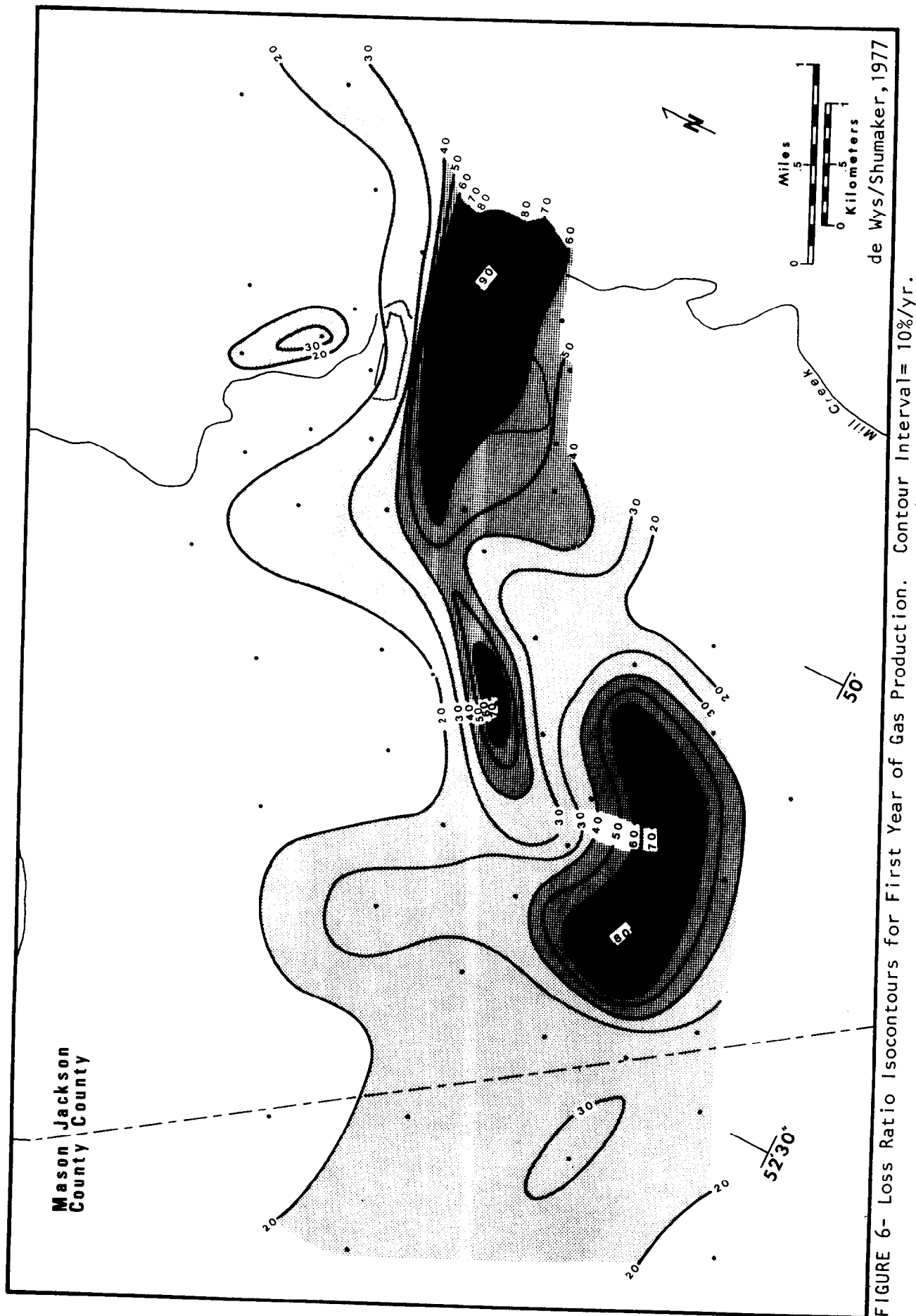


FIGURE 6- Loss Ratio Isocontours for First Year of Gas Production. Contour Interval= 10%/yr. de Wys/Shumaker, 1977





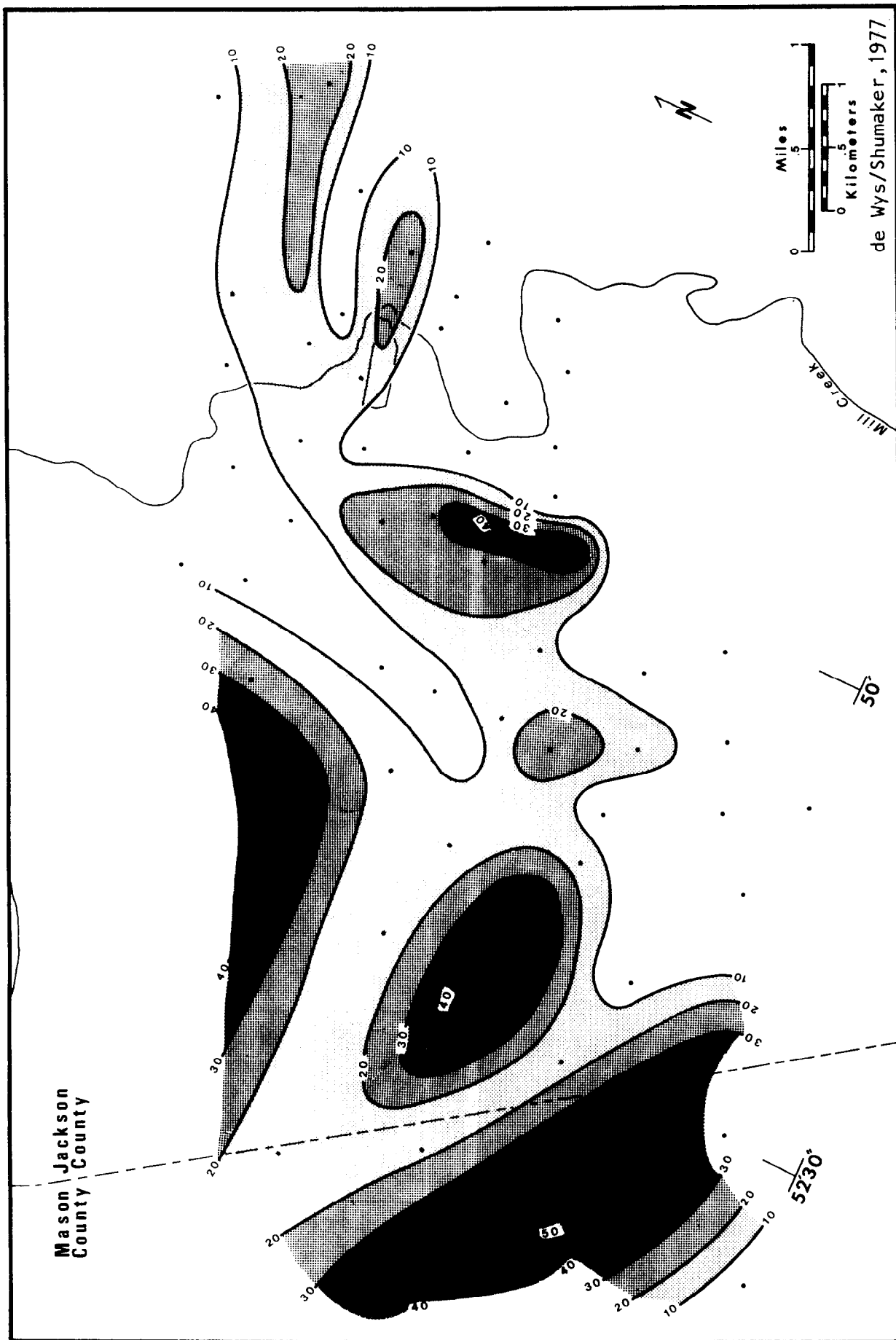


FIGURE 8- Loss Ratio Isocontours for Third Year of Gas Production. Contour Interval=10%/yr.

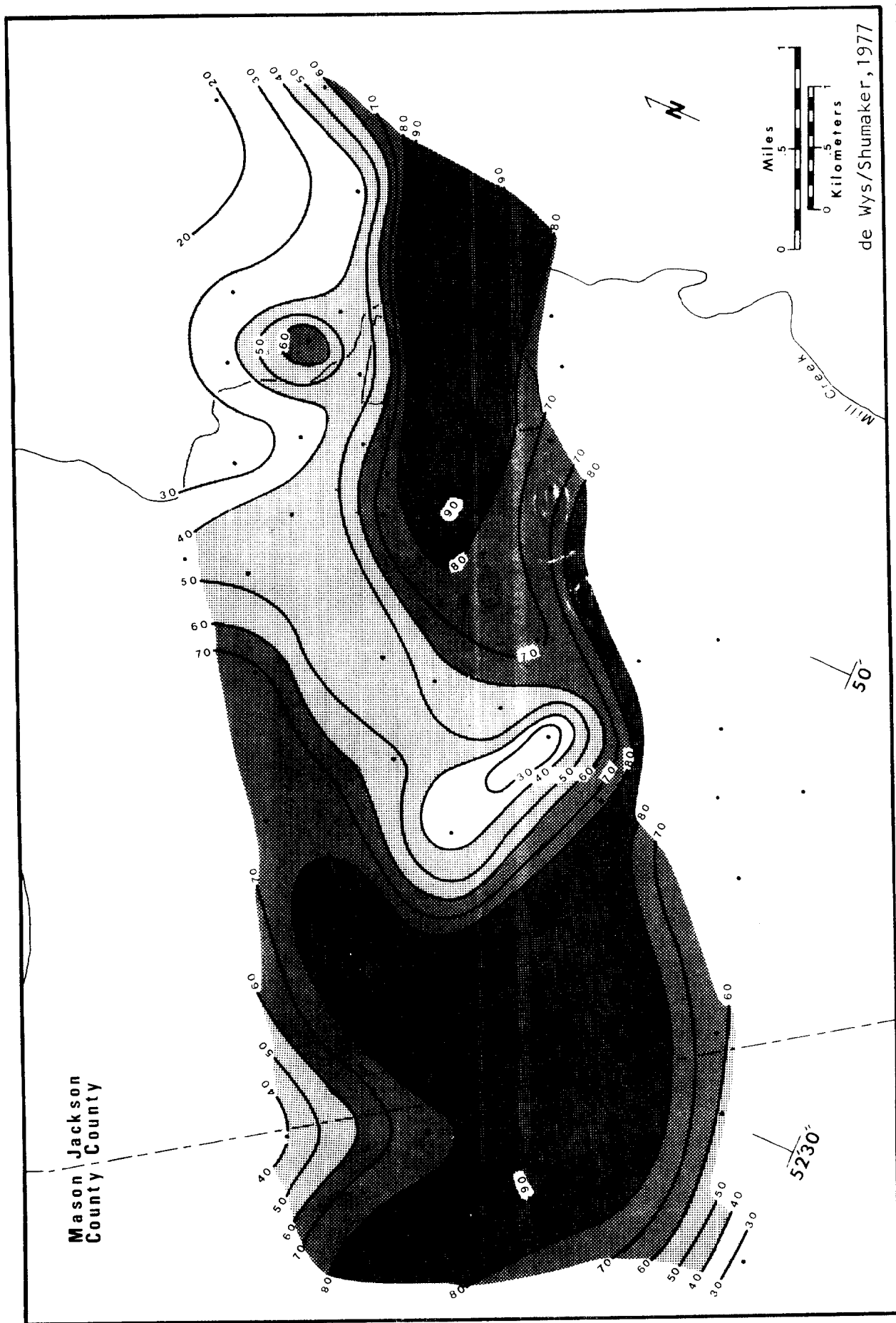


FIGURE 9- Loss Ratio Isocontours for Gas Production Decline from 1st to 5th year of Production. Contour Interval= 10%/yr  
 Loss Ratio =  $(P \text{ 1st yr.} - P \text{ 5th yr.})/P \text{ 1st yr.}$

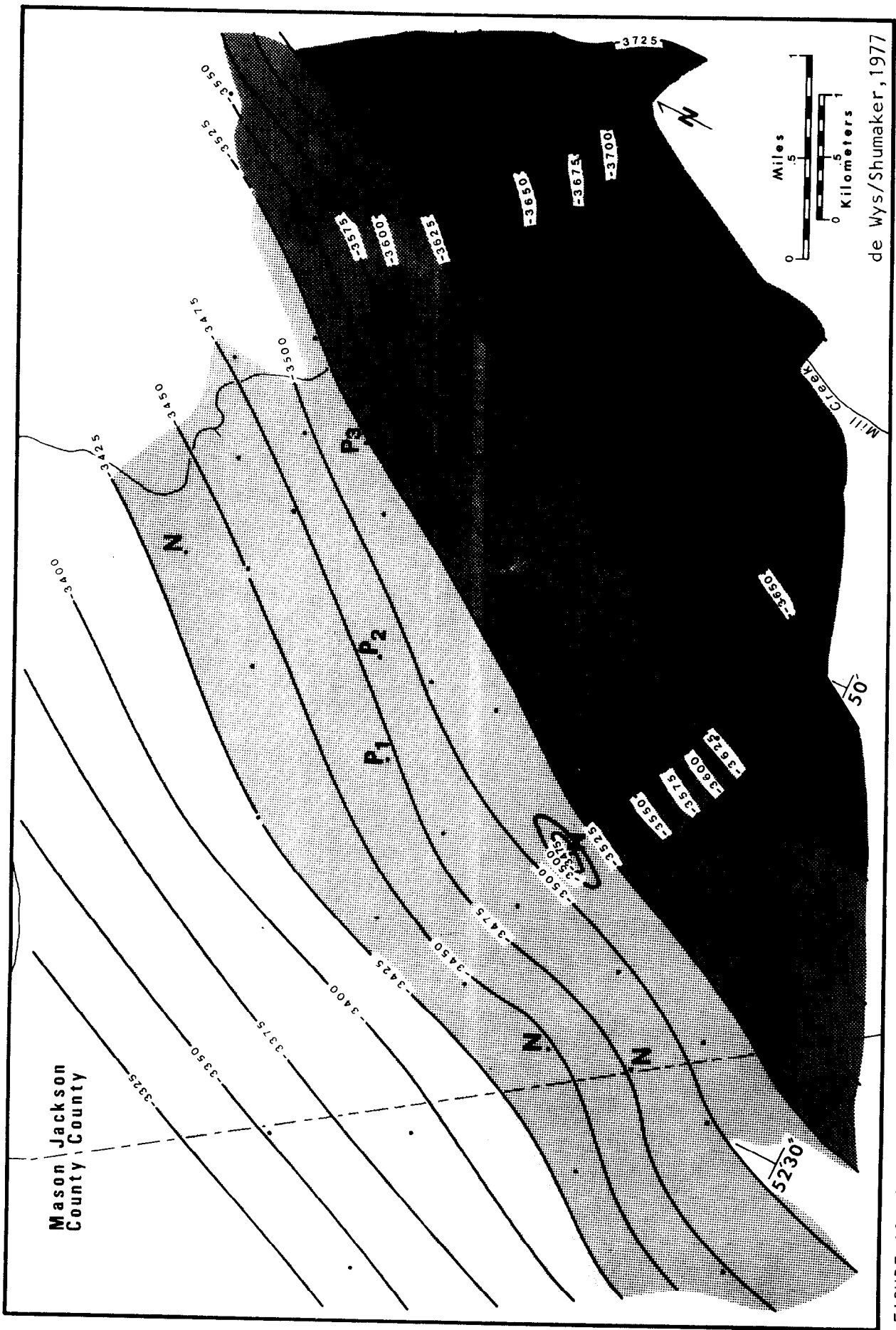


FIGURE 10- Structure Contours on Top of the Onondaga. Contour Interval= 25 ft. New Wells=(N). Wells compared to computer curves=(P). After E.B.Nuckols, 1977.

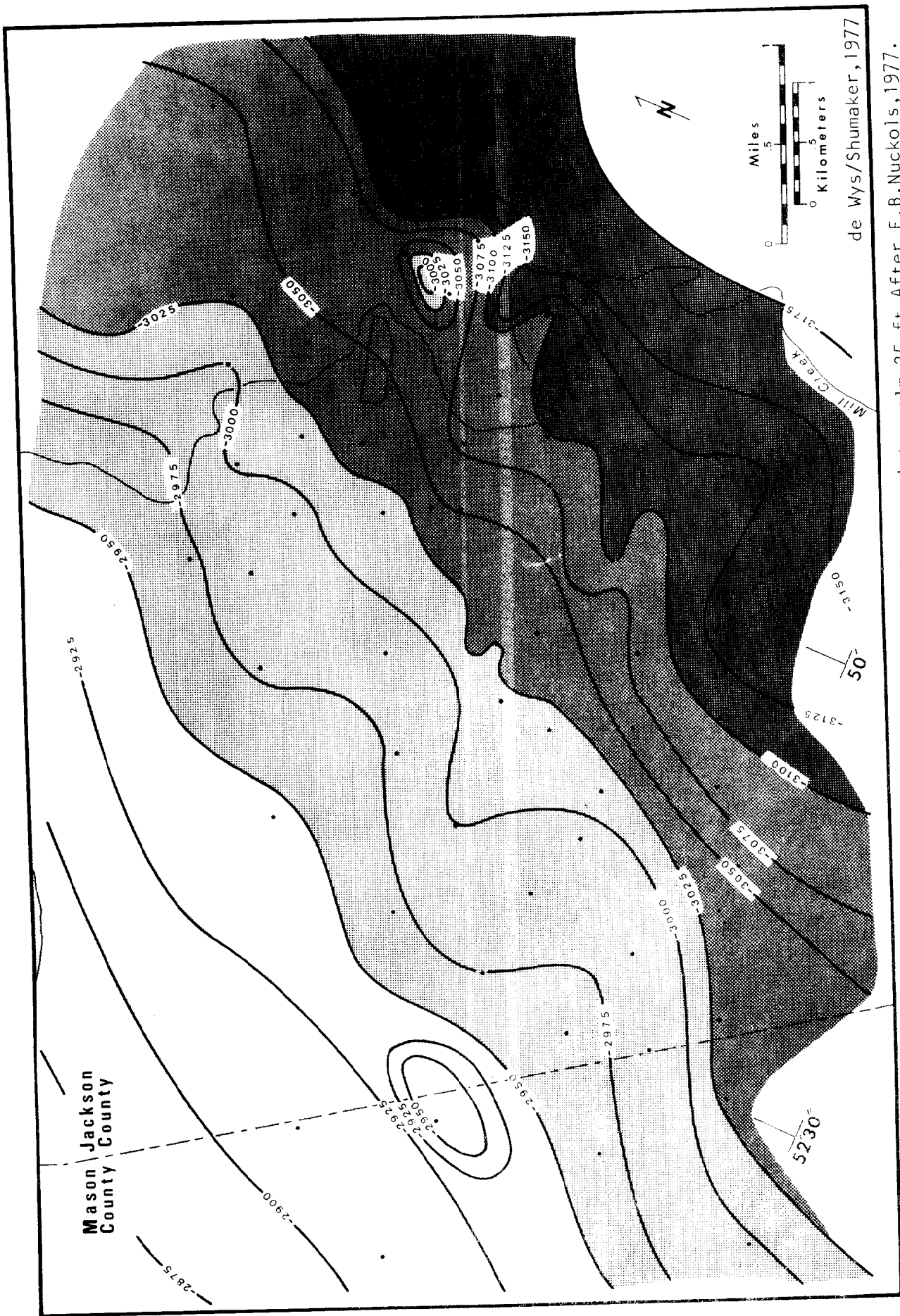


FIGURE 11- Structure Contours on the Bottom of the Huron Shales. Contour Interval= 25 ft. After E.B. Nuckols, 1977.

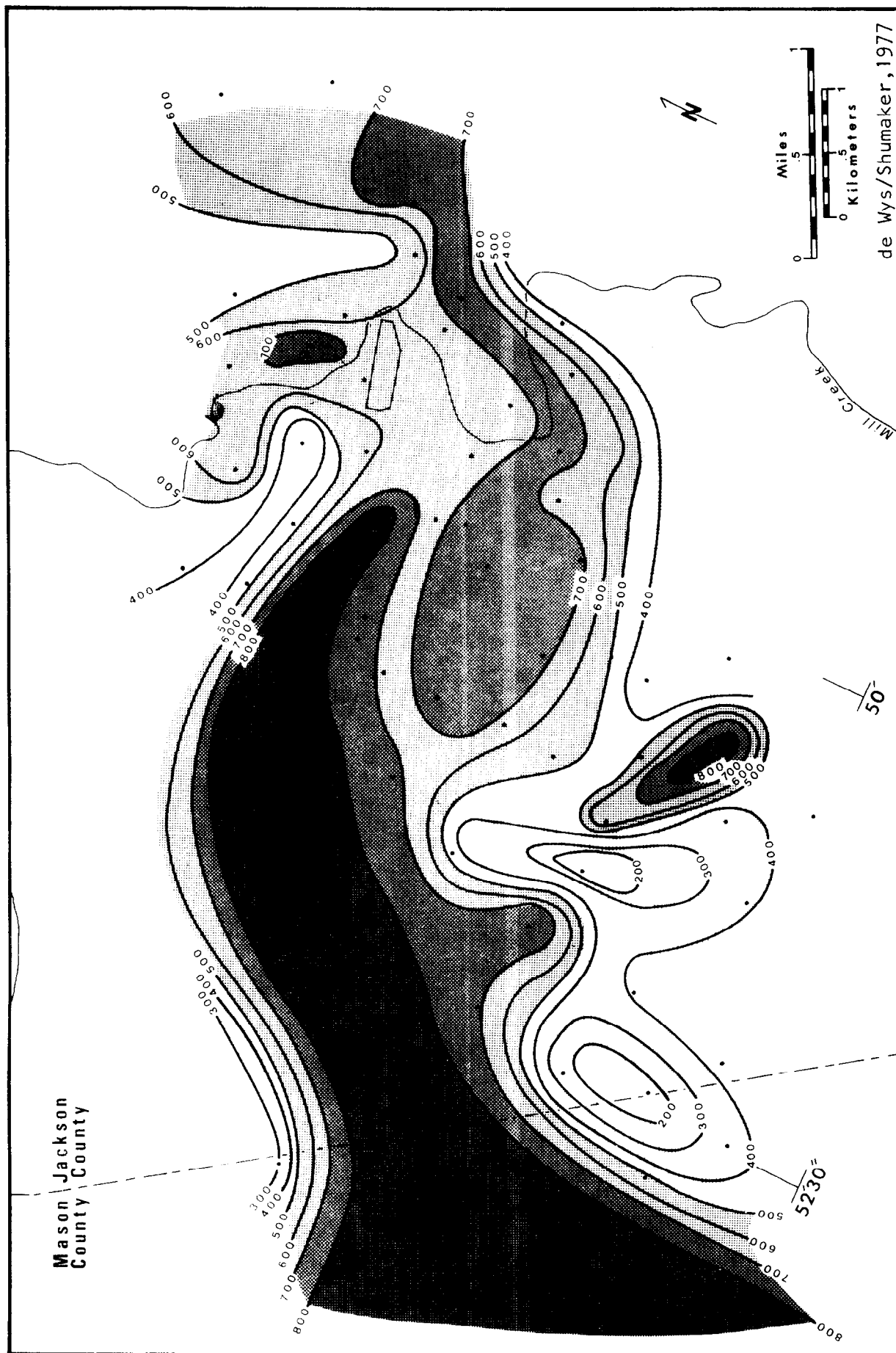


FIGURE 12- Isopressure Contours of Initial Well Pressures. Contour Interval= 100#. t=1930-1976.

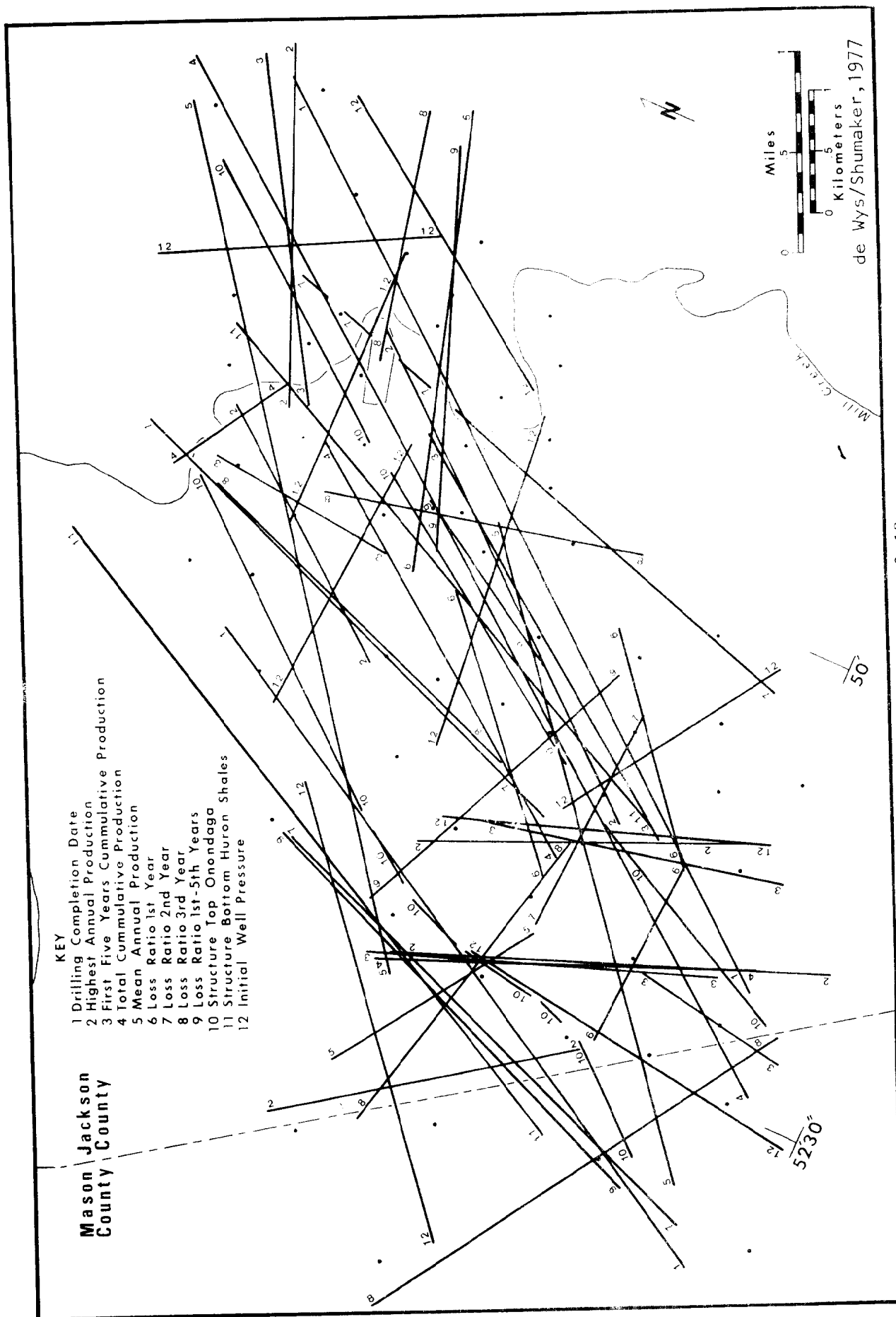
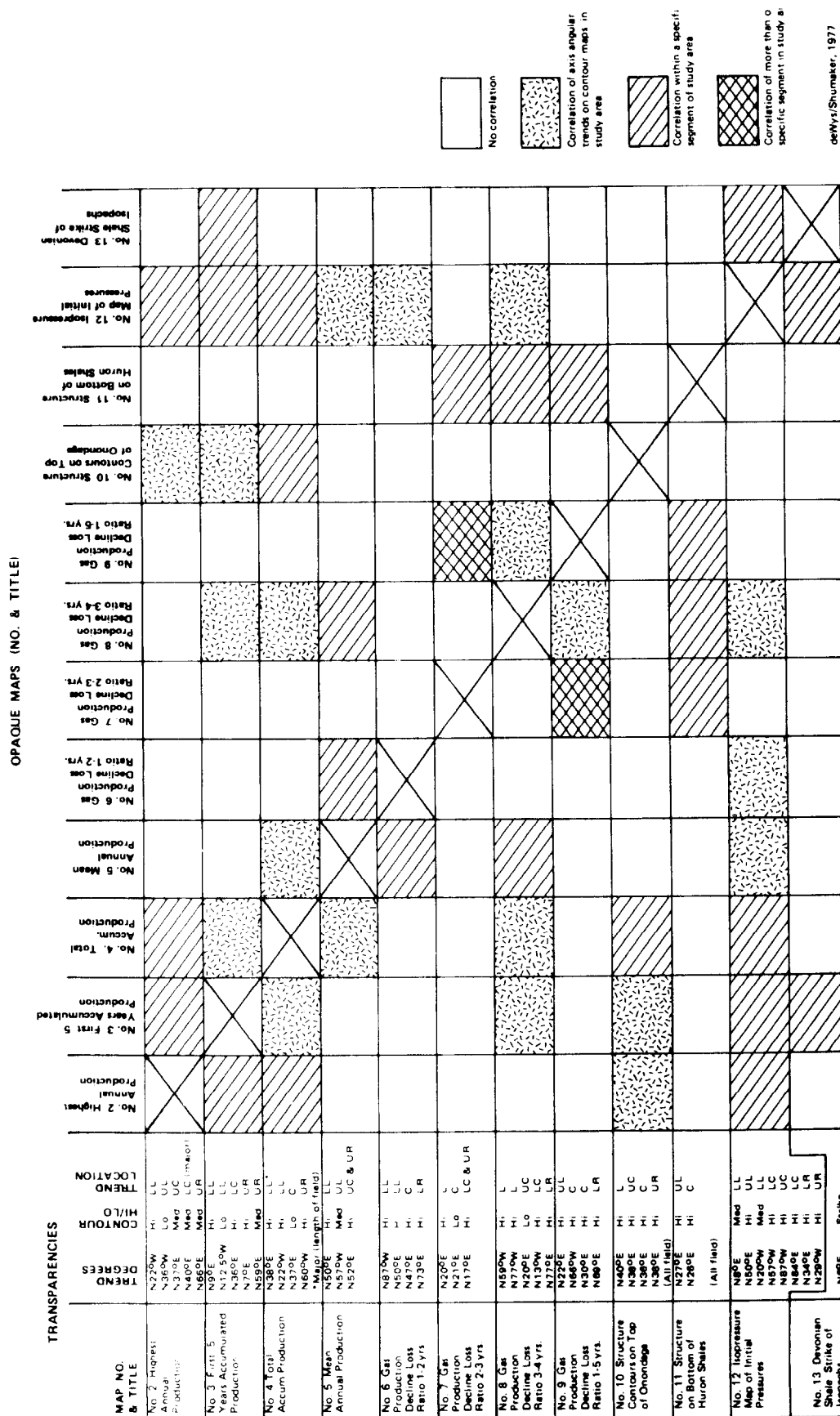


FIGURE 13- Trend Map. Axial Trends of contours from Map Figures 2-12.

FIGURE 14 COMPARISON OF MAP TREND ANGLES IN STUDY AREA AND WITHIN SPECIFIC SEGMENTS OF STUDY AREA



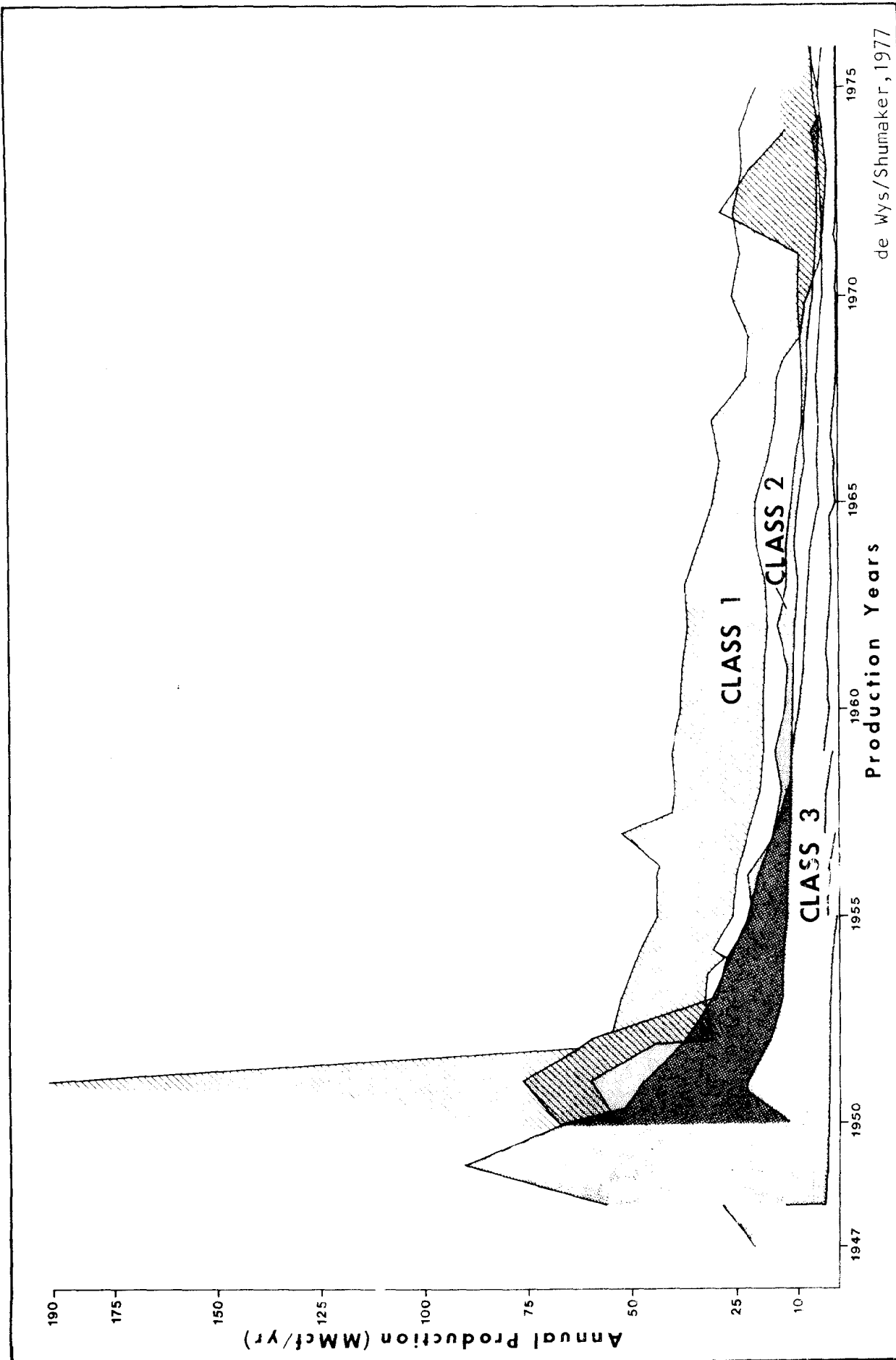
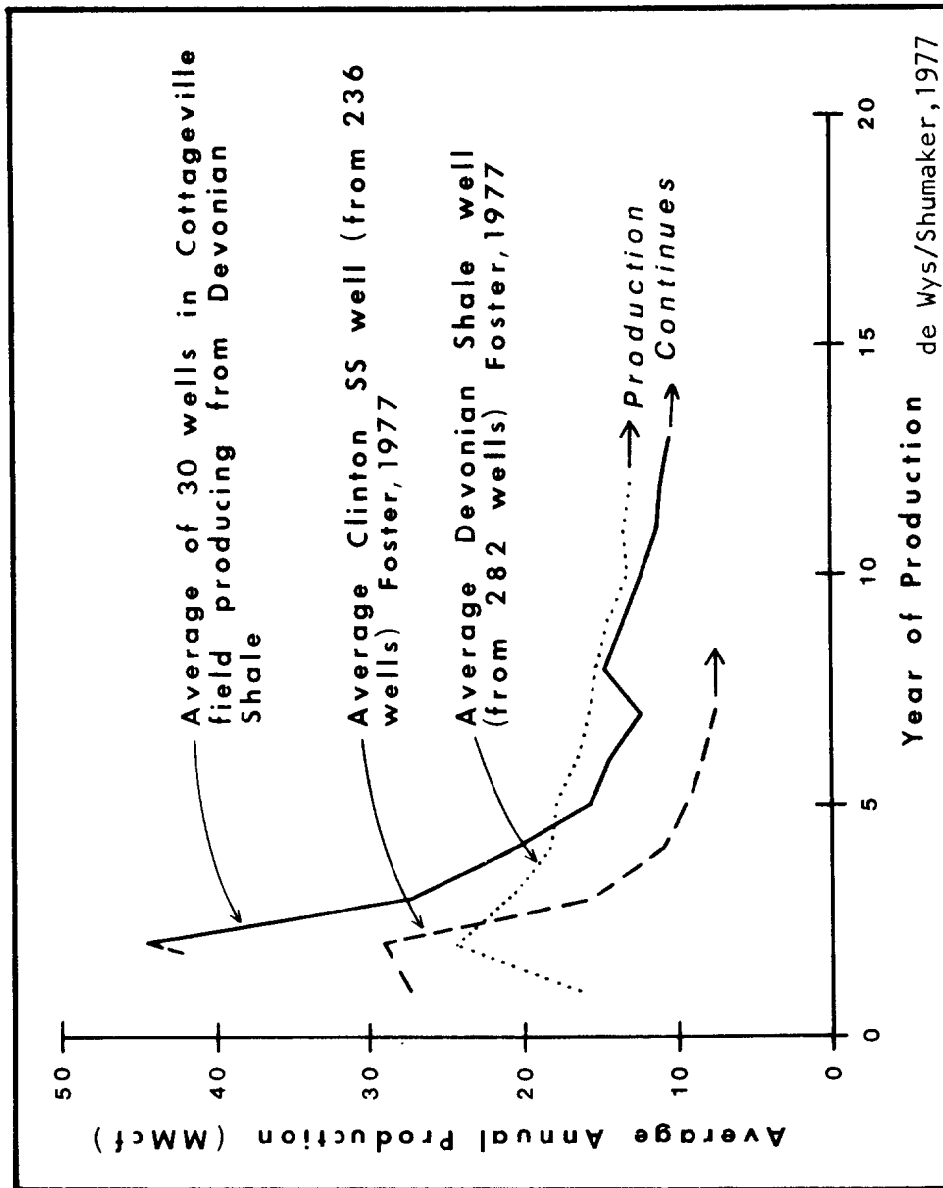


FIGURE 15- Chronological Plot of Field Production Data. Three families of curves are observed.





de Wys/Shumaker, 1977

FIGURE 16- Average Production Decline Curve from 30 Cottageville Wells compared with Average Production Decline Curves of 1) Clinton Sandstone and 2) Devonian Shale Wells in various basin areas. Data for the latter two curves from Foster, 1977.

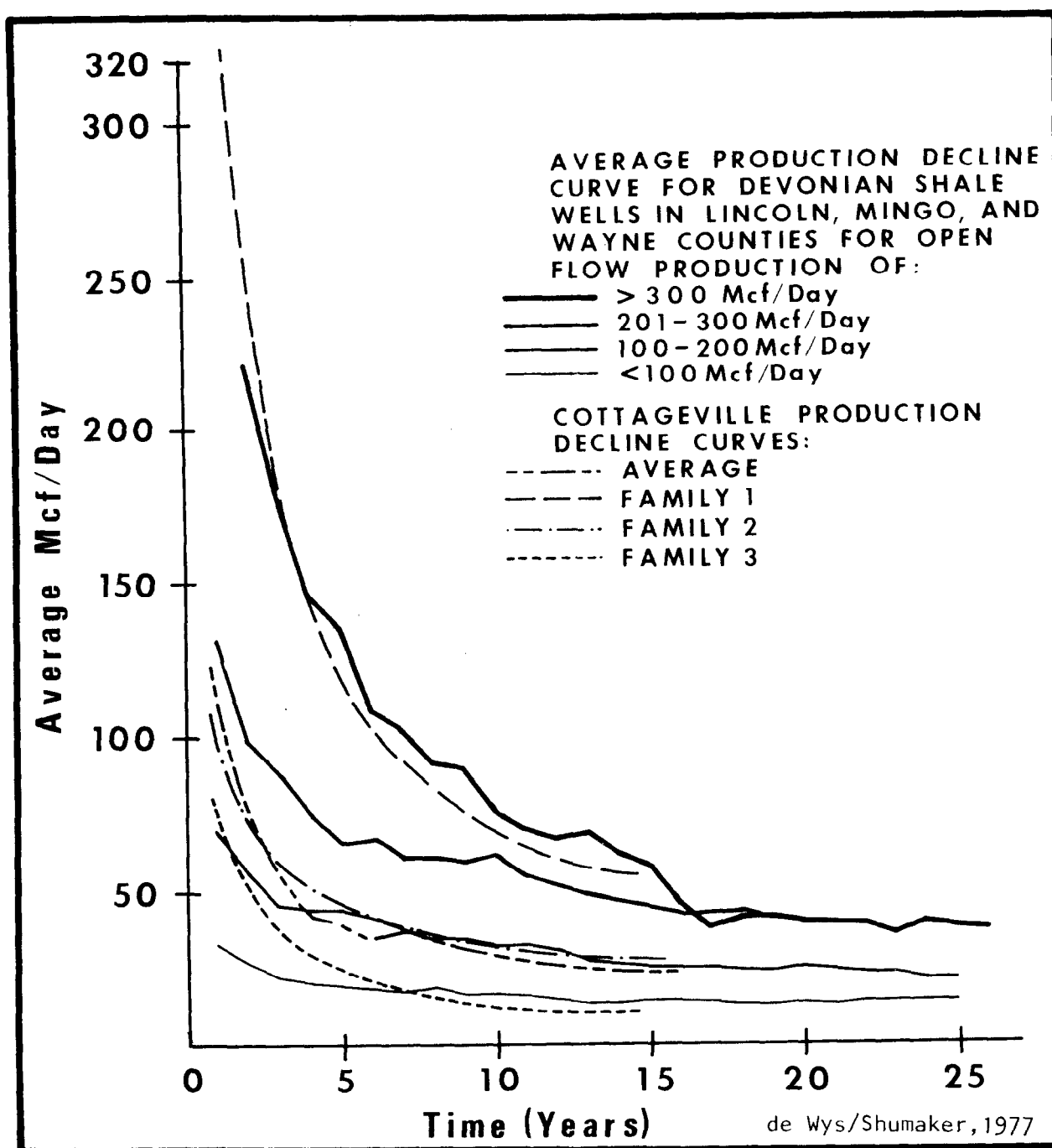


FIGURE 17- Average Cottageville Production Decline Curve and Average Curves for Family Curves #1, #2, and #3, compared with Averaged Production Decline Curves for Devonian Shale Wells in Lincoln, Mingo and Wayne Counties, West Virginia (Bagnall, 1976).

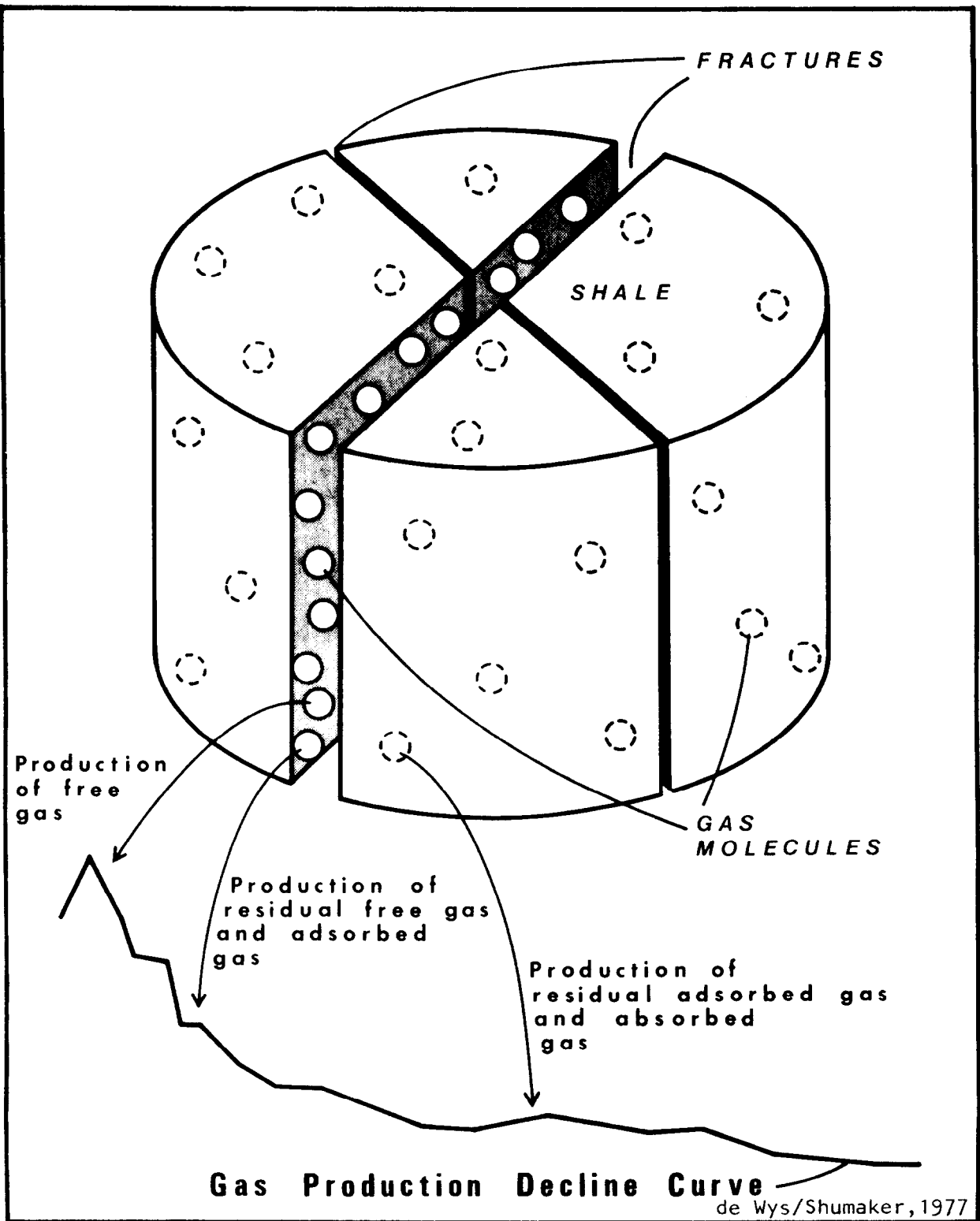


FIGURE 18- Schematic Sketch of Fractures in Devonian Shale & possible relationships of gas.

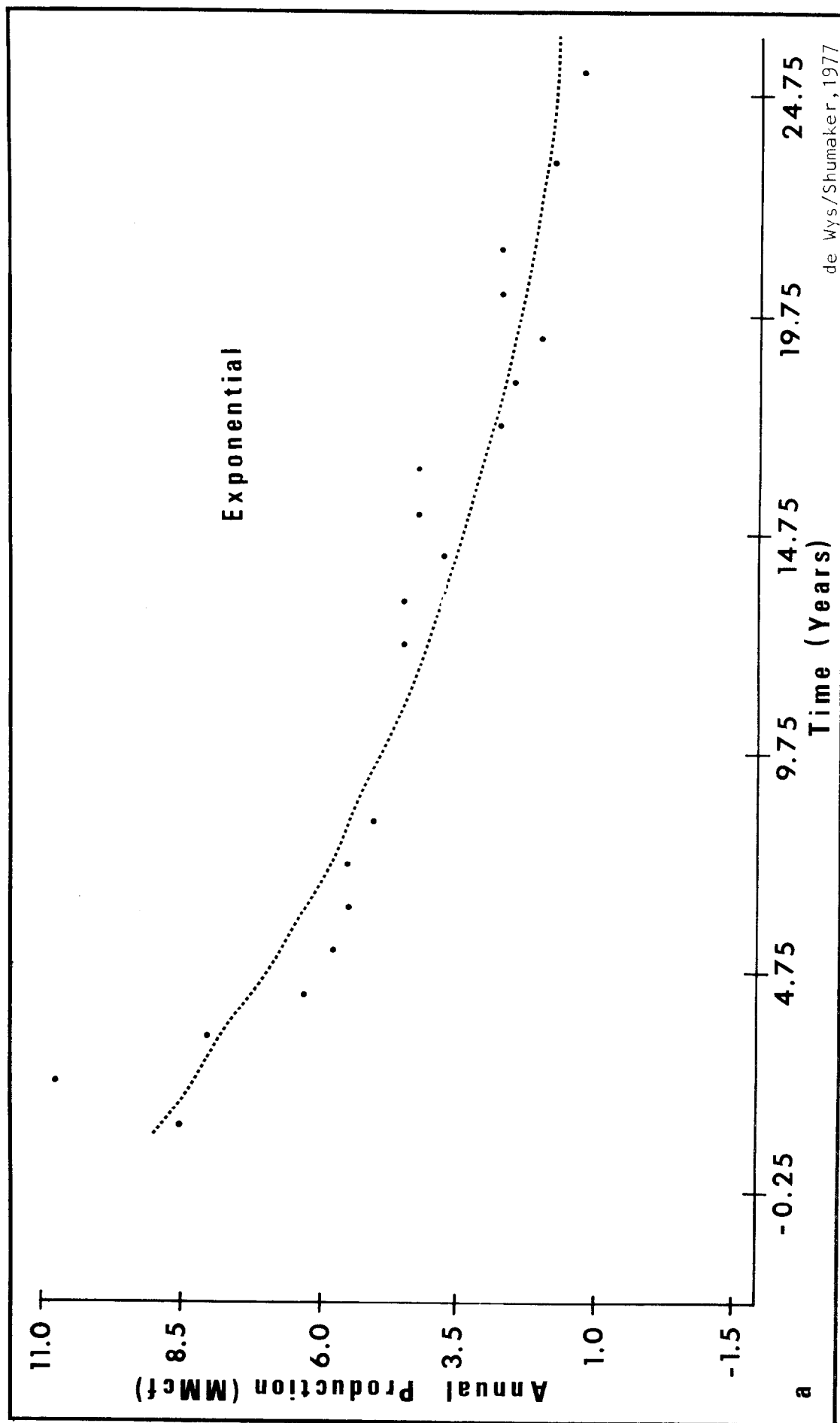


FIGURE 19- A comparison of Best Fit a) Exponential, b) Higher Order Polynomial, and c) Polynomial Reciprocal Curves to Annual Production Data for Well #716 over 27 years.

de Wys/Shumaker, 1977

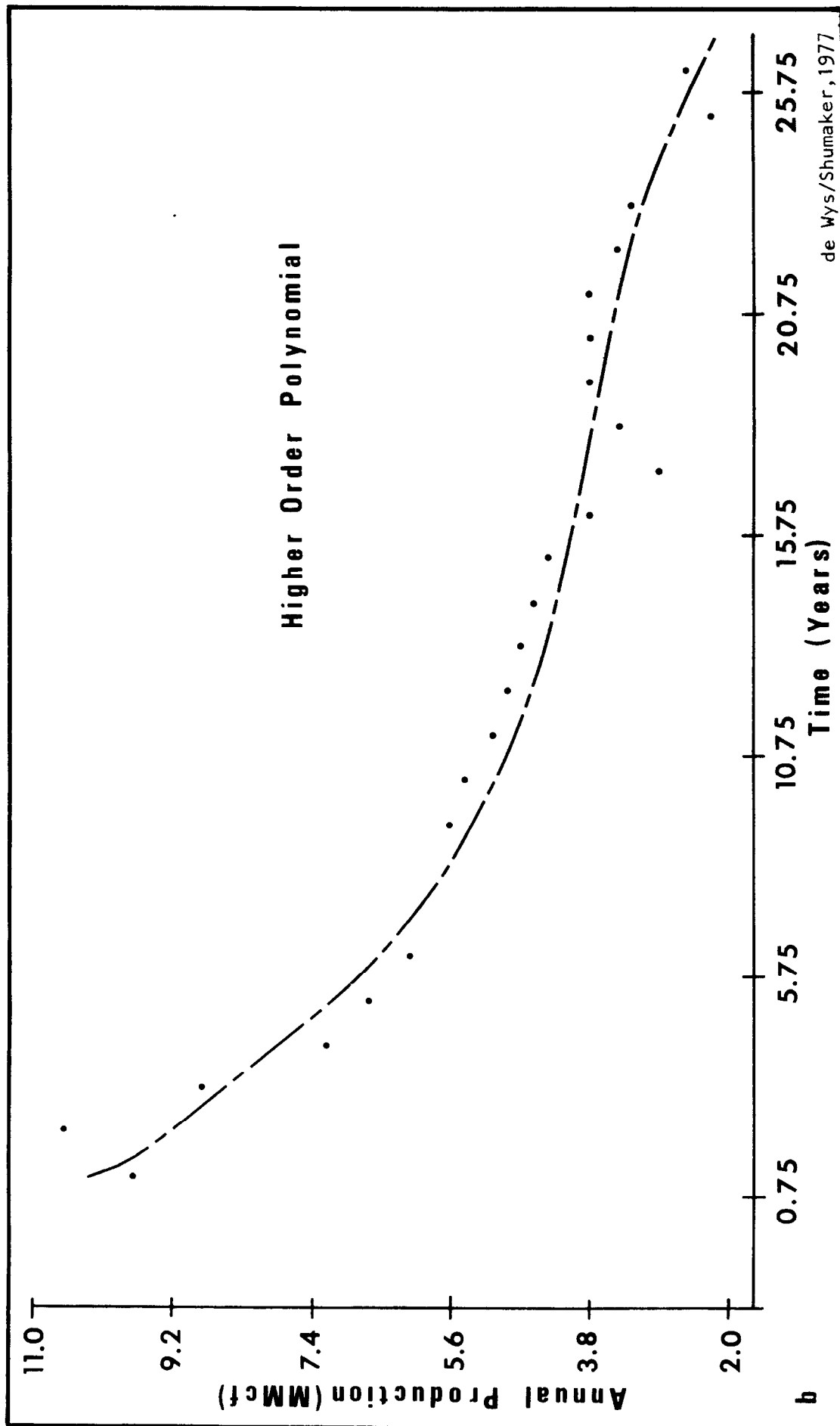
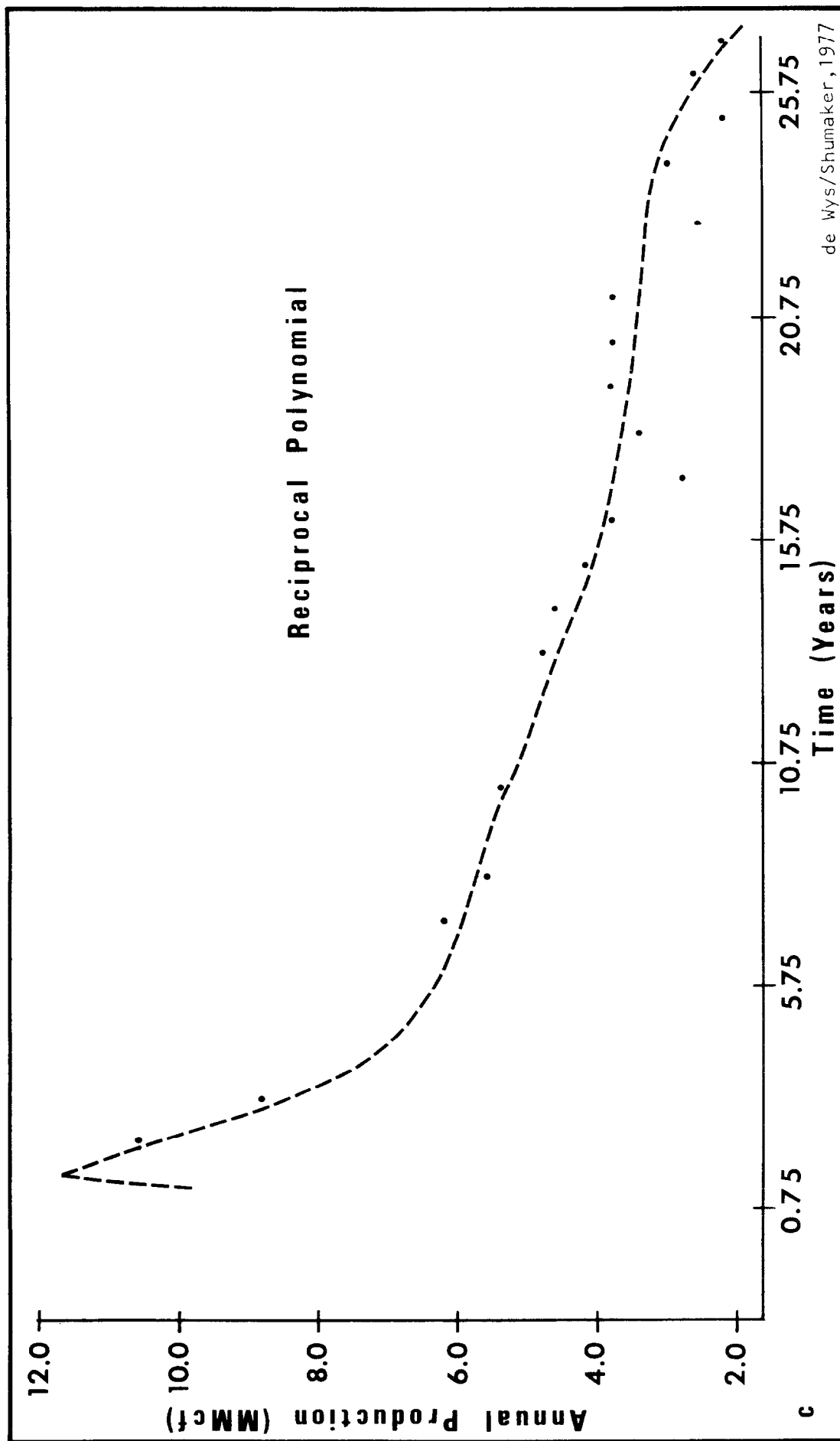


FIGURE 19b Higher Order Polynomial



de Wys/Shumaker, 1977

FIGURE 19c Reciprocal Polynomial

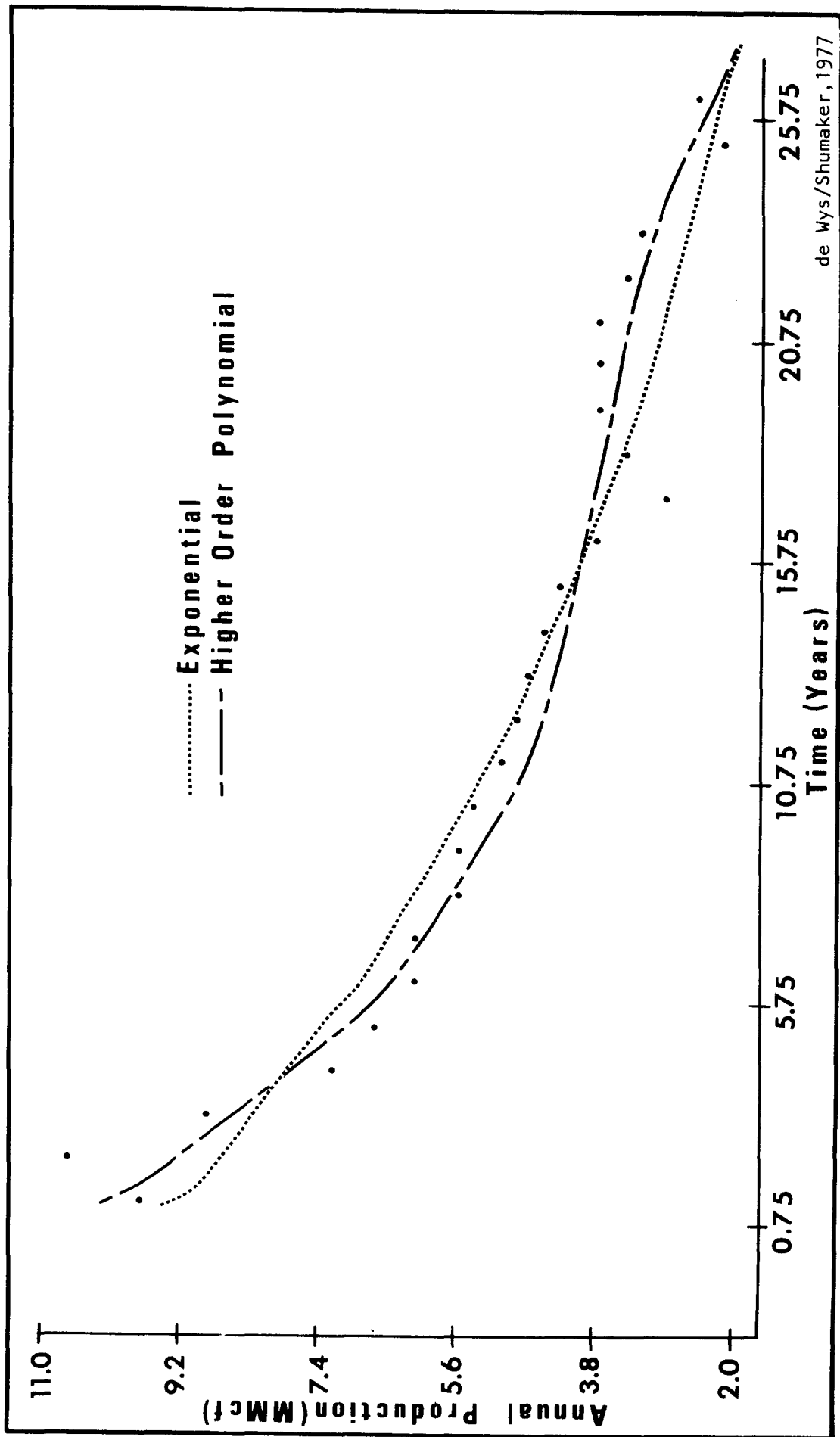


FIGURE 20- Best Fit Exponential and Higher Order Polynomial Curves to Annual Production Data for Well #715 over 26 years.

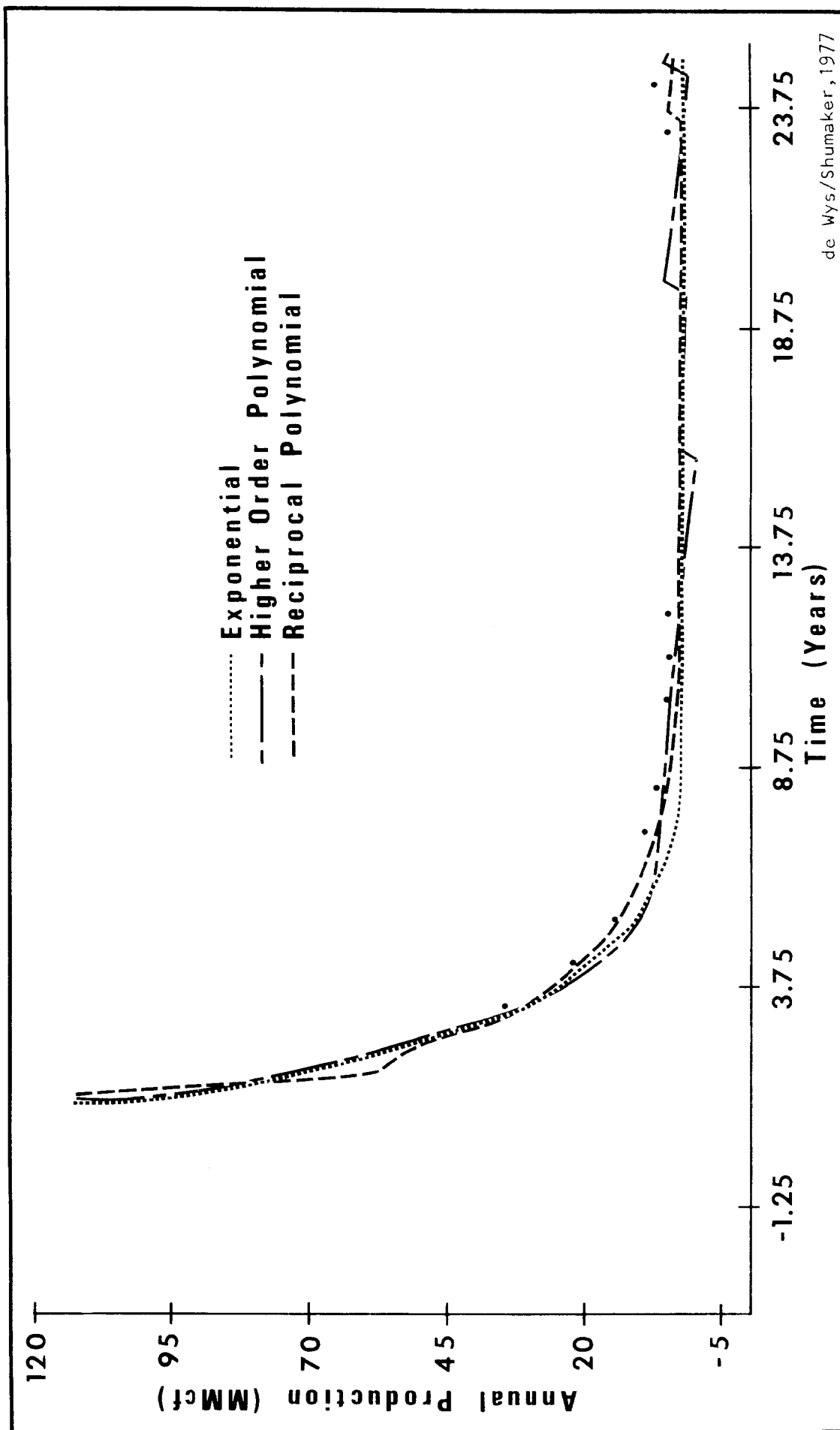


FIGURE 21- Best Fit Exponential and Reciprocal Polynomial Curves to Annual Production Data for Well #694 over 25 years.



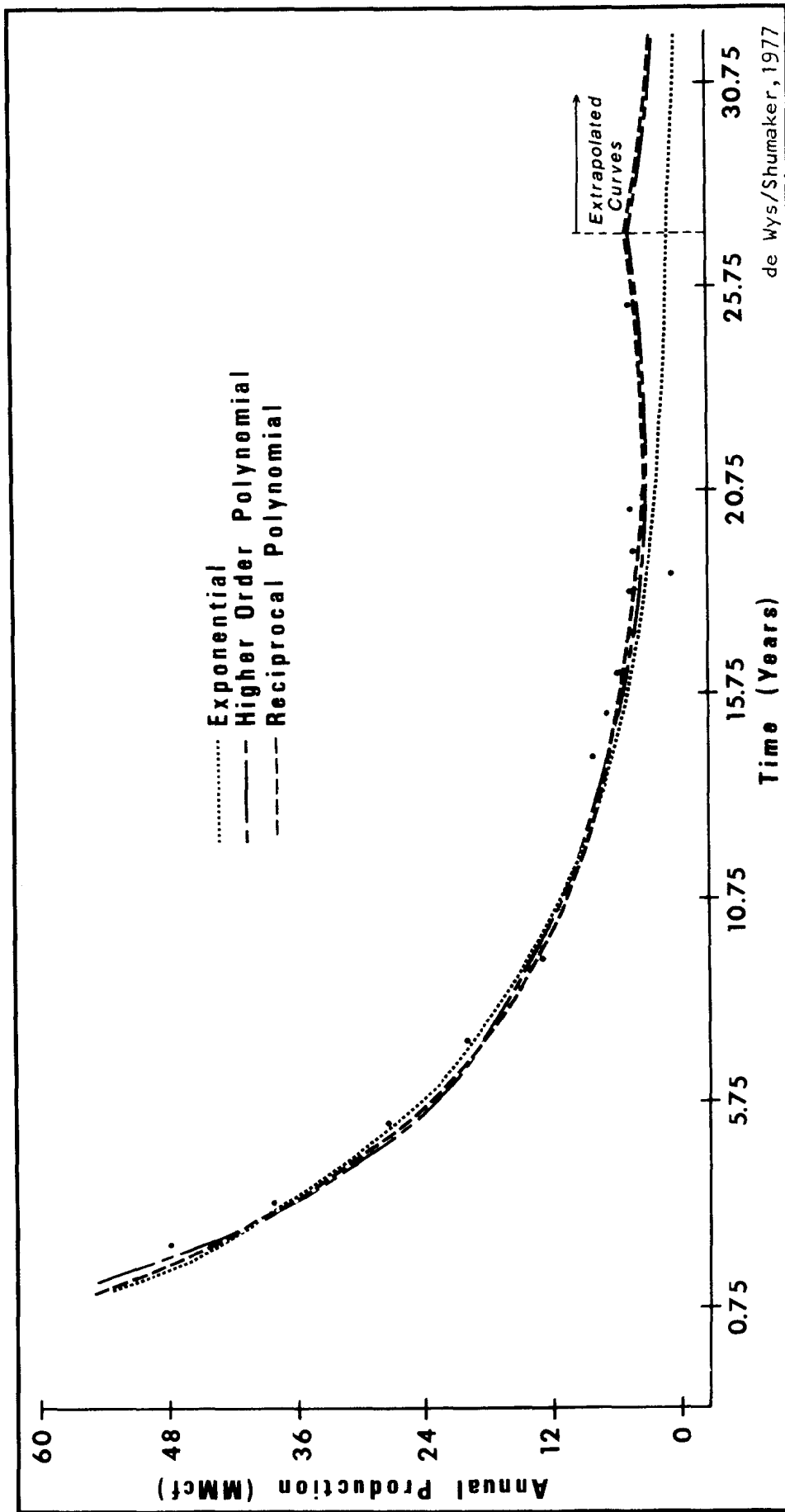


FIGURE 22- Best Fit Exponential, Higher Order Polynomial and Polynomial Reciprocal Curves to Annual Production Data for Well #698 over 26 years with Extrapolated Future Curves.

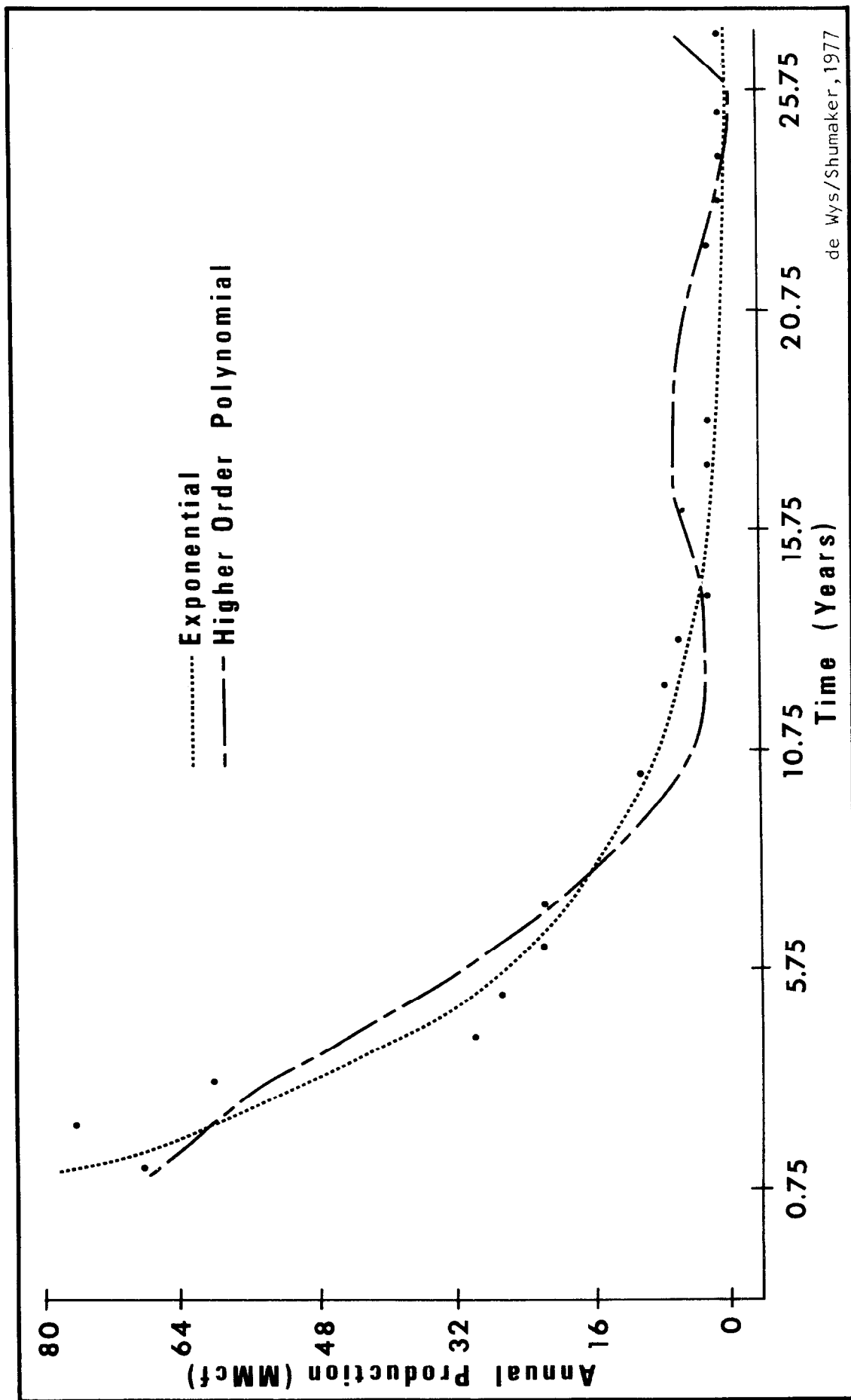


FIGURE 23- Best Fit Exponential and Higher Order Polynomial Curves to Annual Production Data for Well #705 over 27 years.

# LEGEND

## Faults

**Normal**  
**Unclassified**  
 (Solid where mapped,  
 long dashed where approximated,  
 short dashed where inferred)  
**Upthrown side**  
**Downtrown side**  
**Inferred fault trend**  
 determined by magnetic survey

---  
 ---15000---  
**Magnetic Lineations**  
 (Probable Fault)  
**Contours**  
**Wells**  
 \* Gas well  
 \* Show of gas  
 ◇ Dry hole  
 ° Drilling well  
 ° Shut in well  
 . Oil well

Legend for FIGURE 24- Cottageville Field in Relationship to Basement Structures and  
 Magnetic Intensity Contours. From a larger map by Shumaker, 1977. Figure 24 is on  
 the next page.

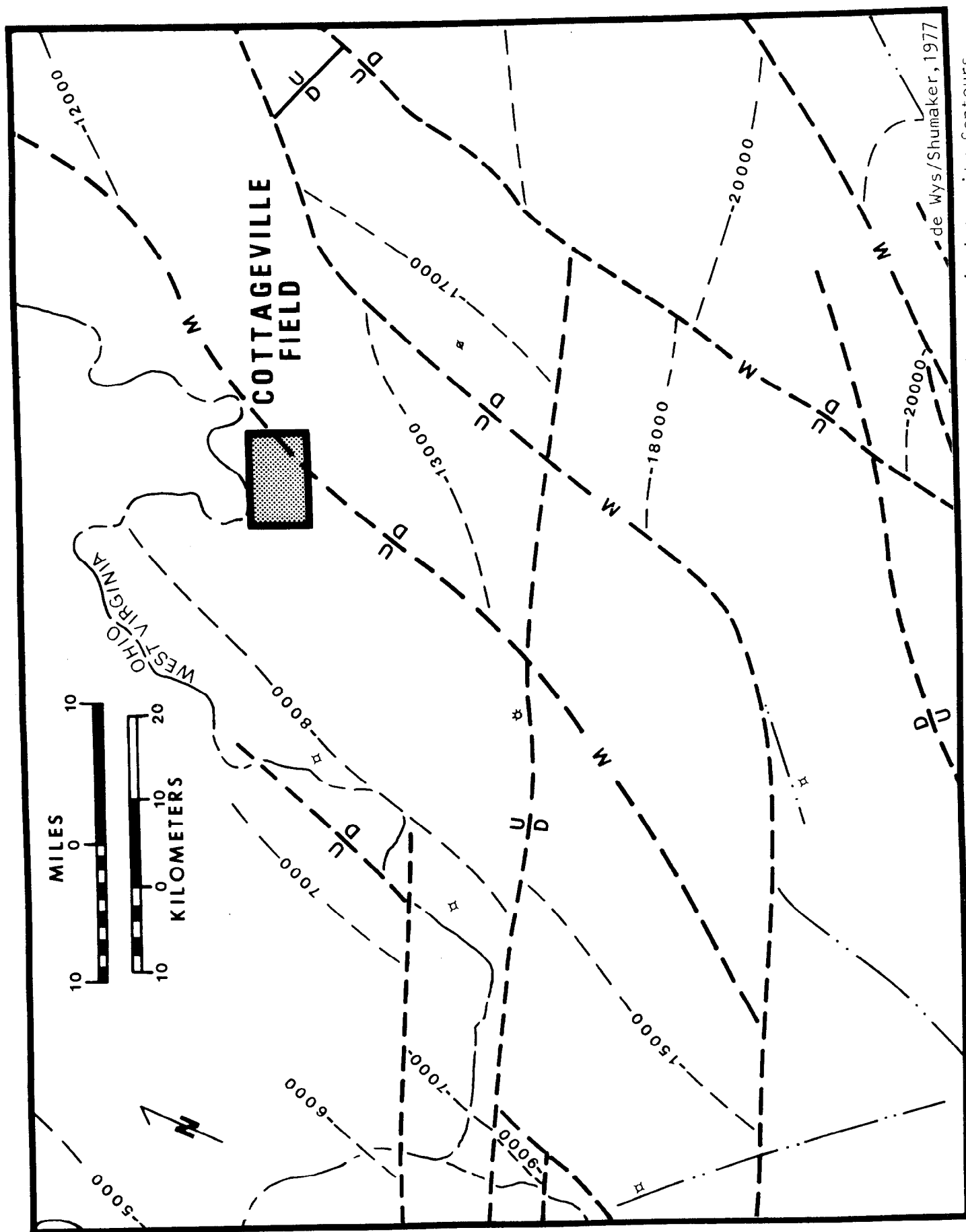


FIGURE 24- Cottageville Field Setting in Relationship to Basement Structures and Magnetic Intensity Contours.

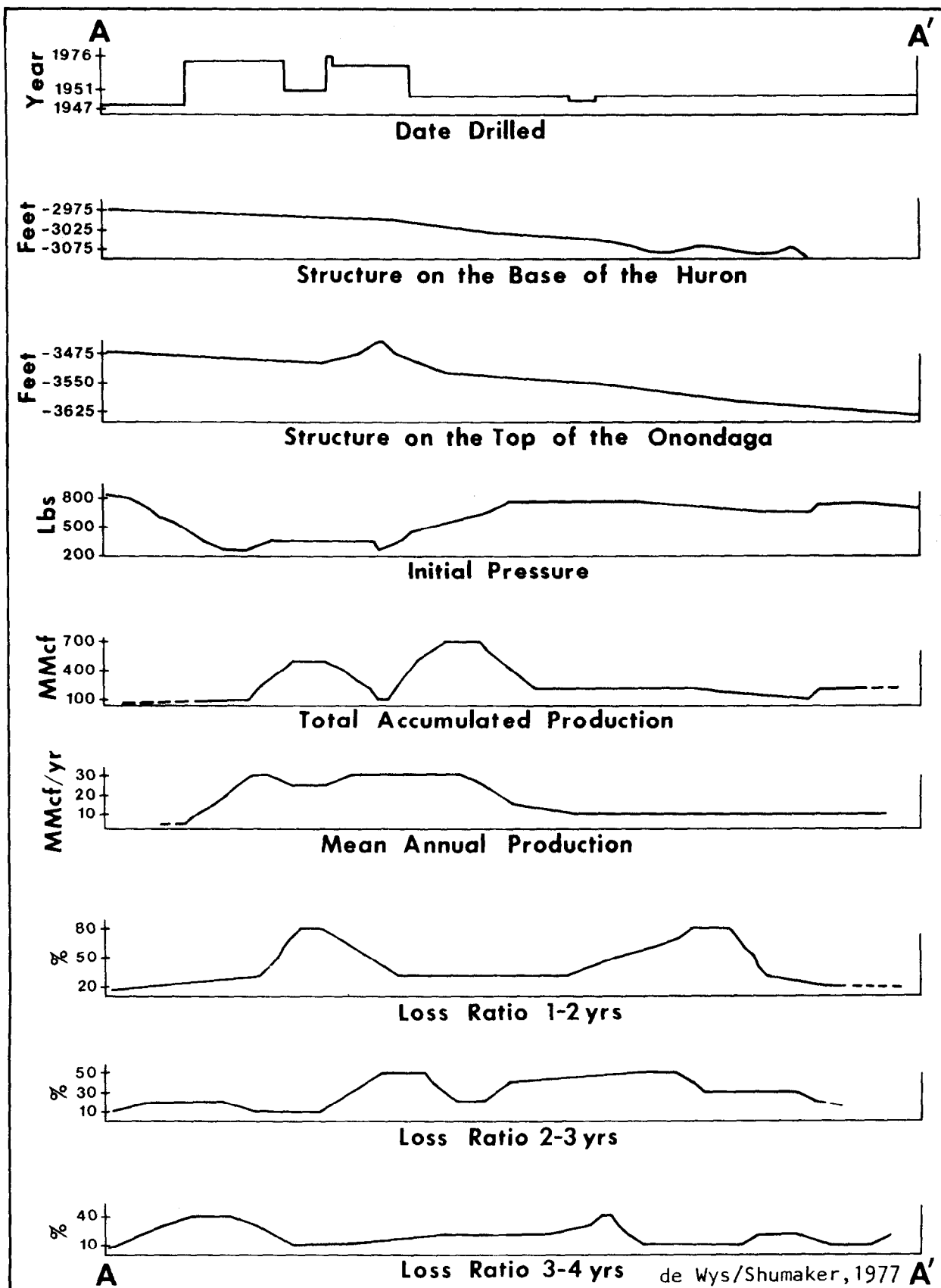


FIGURE 25- Cross Section Comparison of Map Contours of Drilling Dates, Structure on the Base of the Huron, Structure on the Top of the Onondaga, Initial Pressure, Accumulated Total Production, Mean Production, and Loss Ratios for 1st, 2nd, 3rd years of Production.

DATA SHEET

Table 1 Trend Angle Grouping by Angle over Entire Study Area  
(Represented by Outlines of Intersection areas on Figure )

1)	5 - 9 NE	area	2)	20 - 22 NE	area	3)	26 - 30 NE	area
	Up dip trend	5		7	20		11	26
	magnetic survey-basement			9	22		11	27
	Devonian Shale	6					8	28
	3	Total					9	30
	12	7 UR						C
	3	8 LL						UL
		9 LL						UL
								C

4)	36 - 40 NE	area	5)	47 - 52 NE	area	6)	12.5 - 13 NW	area
	10	36 C		6	47 C		3	12.5 LL
	3	36 LC		12	50 UL		8	13 LC
	4	37 C		5	50 LL			
	2	37 UC		6	50 LL			
	10	38 UR		5	52 UC + UR			
	10	38 UC						
	4	38 LL						
	10	40 L						
	2	40 LC						

Up dip trend on magnetic  
survey N38 E R

7)	20 - 22 NW	area	8)	57 - 60 NW	area	9)	87 NW	area
	12	20 LL		12	57 LC		6	87 LL
	4	22 LL		5	57 UL		12	87 UC
	2	22 LL		8	59 L			
				4	60 UR			

UR = upper right section of study area    LC = lower center  
 LL = lower left    UC = upper center  
 C = center    L = left  
 UL = upper left

DATA SHEET

Table 2 Trend Angle Grouping by Angle and Segment

NE area		NE	
7	20 L hi	7	21 C lo
9	26 UL hi	9	30 C hi
11	27 UL hi	11	26 C hi
8	28 UL lo		
10	38 UL hi	4	37 C lo
10	40 L hi	10	36 C hi
12	8 LL med	2	40 LL med
3	9 LL hi	3	36 LC hi
13	6 total		
5	50 LL hi		
6	50 LL hi		
NW			
5	57 UL med		
8	59 L hi		
2	22 LL hi		
4	22 LL hi		
12	20 LL med		

L = left section of study area  
 UL = upper left  
 LL = lower left  
 C = center  
 LC = lower center

Table 3 Trend Correlation

#	Map	Correlates with Segment	Correlates with other Area Trends
2	Highest Annual Production	3 1st 5 years Accum. Prod. 4 Total Accum. Prod. 12 Isopressure: Initial Pressure	10 Structure Top of Onondaga
3	First 5 years Production	2 Highest Annual Prod. 12 Isopressure: Initial Pressures 13 Devonian Shale Isopachs	4 Total Accum. Prod. 8 Gas Prod. Decline Loss Ratio 3-4 yrs. 10 Structure Top of Onondaga
4	Total Accum. Production	2 Highest Annual Prod. 12 Isopressure: Initial Pressures 13 Devonian Shale Isopachs	4 Total Accum. Prod. 8 Gas Prod. Decline Loss Ratio 3-4 yrs. 10 Structure Top of Onondaga
5	Mean Annual Prod.	6 Gas Prod. Decline Loss Ratio 1-2 yrs. 8 Gas Prod. Decline Loss Ratio 3-4 yrs.	4 Total Accum. Prod. 12 Isopressure: Initial Pressures
6	Gas Prod. Decline Loss Ratio 1-2 yrs.	5 Mean Annual Prod.	12 Isopressure: Initial Pressures
7	Gas Prod. Decline Loss Ratio 2-3 yrs.	9 Gas Prod. Decline Loss Ratio 1-5 yrs. 11 Structure Bottom of the Huron Shale	
8	Gas Prod. Decline Loss Ratio 3-4 yrs	5 Mean Annual Prod. 11 Structure Bottom of Huron Shale	3 1st 5 yrs Accum. Prod. 4 Total Accum. Prod. 9 Gas Prod. Decline Loss Ratio 1-5 yrs. 12 Isopressure: Initial Pressures



Table 3 continued

#	Map	Correlates with Segment	Correlates with other Area Trends
9	Gas Production Decline Loss Ratio 1-5 yrs.	7 Gas Prod. Decline Loss Ratio 2-3 yrs. 11 Structure Bottom of Huron Shale	8 Gas Prod. Decline Loss Ratio 3-4 yrs.
10	Structure Contours on top of Onondaga	4 Total Accum. Prod.	2 Highest Annual Prod. 3 First 5 years Accum. Prod.
11	Structure Bottom of Huron Shales	7 Gas Prod. Decline Loss Ratio 2-3 yrs. 8 Gas Prod. Decline Loss Ratio 3-4 yrs. 9 Gas Prod. Decline 1-5 yrs.	
12	Isopressure: Initial Pressures	2 Highest Annual Prod. 3 First 5 yrs Accum. Prod. 4 Total Accum. Prod. Devonian Shale Isopachs	5 Mean Annual Prod. 6 Gas Prod. Decline 1-2 yrs 8 Gas Prod. Decline 3-4 yrs

Table 4 Comparison of Fracture Orientations  
in the Core of the L. A. Baler Well in Jackson County,  
West Virginia (Patchen and Larese, 1976) with Map Trends  
in the Present Study

Section of core	% of measured fractures	orientation direction with fractures	Maps with which correlation is observed in trend directions
Core above pay zone	80%	N 40 - 50 E	1) Highest Annual Production 2) Mean Annual Production 3) Gas Production Decline Loss Ratio 1-2 years 4) Structure contours on top of Onondaga (strike) 5) Isopressure - Initial Pressure
Lower portion of core where gas shows are noted	21%  14%	N 40 - 50 E  N 10 - 15 W	1) First Five Years Accum. Prod. (1) 2) Gas Prod Decline Loss Ratio 3-4 yrs 1) Gas Prod Decline Loss Ratio 2-3 yrs 2) Gas Prod Decline Loss Ratio 3-4 yrs
Basal portions of core	13%	N 85 - 89 W	1) Gas Prod Decline Loss Ratio 1-2 yrs 2) Initial Pressure 3) Up dip of Devonian Isopachs

Table 5 R<sup>2</sup>Values for Best Fit Curves to Well Data

<u>Well</u>	<u>Exponential</u>	<u>Higher Order Polynomial</u>	<u>Polynomial Riciprocal</u>
715	92.18%	95.95%	98.28%
716	90.06%	92.6%	98.29%
694	98.71%	98.82%	99.83%
698	98.74%	99.82%	99.86%
705	95.37%	93.54%	99.11%